Fewer complications result from a video-assisted approach to anatomic resection of clinical stage I lung cancer

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Objectives: Anatomic resection is currently the standard of care for clinical stage I lung cancer, yet clinicians increasingly pursue nonsurgical, ablative therapies to avoid the morbidity of thoracotomy. The video-assisted thoracic surgery (VATS) approach is a minimally invasive alternative to thoracotomy yet the effect of VATS on the morbidity of patients undergoing lung cancer resection is not fully characterized. We evaluated complications following anatomic resection of clinical stage I lung cancer by VATS and thoracotomy to clarify the effect of the minimally invasive approach.

Methods: The Society of Thoracic Surgeons database was queried for lobectomies and segmentectomies performed between 2001 and 2010 for clinical stage I primary cancer.

Results: A total of 11,531 (7137 open and 4394 VATS) patients with clinical stage I primary lung cancers underwent resection. Propensity scoring was used to match cases into 2745 well-balanced pairs. Overall complications were significantly more likely in the thoracotomy group (36%) than in the VATS cohort (30%; $P < .001$). Patients undergoing thoracotomy experienced significantly more pulmonary complications (21% vs 18%), atrial arrhythmias (13% vs 10%), and were more likely to undergo transfusion (6% vs 4%). Operative mortality was similar (thoracotomy 1.8%, VATS 1.3%; $P = .13$).

Conclusions: Anatomic resection of early stage lung cancer is performed with a low mortality rate, according to data from the Society of Thoracic Surgeons database. Perioperative complications are significantly less likely to occur when patients with stage I lung cancers undergo resection using the VATS approach. Further study is warranted to determine long-term effects of these differences in perioperative outcomes. (J Thorac Cardiovasc Surg 2014;148:637-43)

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Stage I lung tumors are likely to become most common presentation of primary lung cancer as a result of progressive adoption of screening with computed tomography scanning. Results from the landmark National Lung Screening trial suggest the prevalence of stage I non-small cell lung cancer (NSCLC) at presentation will increase from 20% to 25% of patients with NSCLC to >60%.¹

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Therefore a comprehensive understanding of treatment-associated morbidity in early stage lung cancer is critical.

Anatomic pulmonary resection is currently the standard of care for the treatment of clinical stage I lung cancer,² yet concerns over the morbidity associated with a traditional thoracotomy have motivated patients and clinicians to pursue less-invasive strategies for lung cancer management. Video-assisted thoracic surgery (VATS) is a minimally invasive alternative to thoracotomy for anatomic lung cancer resection that is associated with less discomfort, shorter hospitalization, and a faster recovery.^{3,4} However, the effect of surgical approach on complication rates in clinical stage I cancer has been incompletely addressed. Therefore, we examined complication rates following anatomic resection in patients with clinical stage I NSCLC via VATS and thoracotomy by Board-certified thoracic surgeons to determine the result of approach on operative morbidity.

METHODS

The Society of Thoracic Surgeons General Thoracic Database (STS-GTD) was queried for surgically managed primary lung cancer. Eligible patients included those undergoing anatomic pulmonary resections for treatment naïve, clinical stage T1 N0 M0 and T2 N0 M0 primary lung cancer in the STS-GTD between 2001 and 2010. During 2009, the stage classification system was modified from the sixth edition of the American Joint Committee on Cancer staging manual (56% of our study population), to the seventh edition (44%). Of the 24,626 primary lung cancer patients in the STS-GTD, 18,928

Abbreviations and Acronyms

NSCLC	= non-small cell lung cancer
STS-GTD	= Society of Thoracic Surgeons General Thoracic Database
VATS	= video-assisted thoracic surgery

(77%) contained sufficiently complete clinical staging information to be considered. This figure improved over the course of the study, with 93% of cases containing complete clinical staging information in 2009 and 2010. We excluded patients with missing data for the pathologic N variable, or who were pathologically staged to be N3 (8 patients). The study population contained insufficient numbers of minimally invasive pneumonectomies (VATS = 17 patients), bilobectomies (VATS = 70), and sleeve lobectomies (VATS = 10) for meaningful comparison and were therefore excluded from both cohorts. The current version of the database does not distinguish VATS segmentectomies from VATS lobectomies and therefore lobectomies and segmentectomies were analyzed as a combined group for both thoracotomy and VATS cohorts for the entire study period. The rates of segmentectomy in the previous version of the database that did distinguish VATS lobectomy from segmentectomy (STS-GTD 2.07) were similar (thoracotomy 6.5% and VATS 8%). Between 2001 and 2010, a total of 11,531 lobectomies or segmentectomies (7137 via thoracotomy and 4394 VATS) for clinical stage I primary lung cancer were recorded in the STS-GTD.

The STS-GTD is a voluntary database, but participants are bound by contract to submit complete unselected cases and are provided with yearly reports concerning missing or outlier data. The STS-GTD has been subjected to external audit annually, beginning in 2010. Approximately 5% of the data were audited and the overall accuracy was 93%.

Conversions

There is not a field in the STS-GTD to indicate a conversion from VATS to thoracotomy. However in version 2.07 of the STS-GTD data form an approach field exists that allows abstractors to select >1 approach. Cases of lobectomy or segmentectomy coded with both thoracoscopy and thoracotomy as the surgical approach were considered combined procedures (potentially representing conversions). Version 2.081 allowed primary procedures as well as secondary procedures to be captured. Primary procedures coded as lobectomy or segmentectomy by thoracotomy, with a secondary VATS procedure on the same day were considered to have had a combined approach (potentially representing a conversion).

Statistics

The Duke Clinical Research Institute supervised all statistical analysis. Comparisons of patient characteristics between groups were made using the 2-sample nonparametric Wilcoxon test for continuous variables and the χ^2 test for categorical variables. Multivariable analysis utilized logistic regression. *P* values were not adjusted for multiplicity.

Annual study case volume of lobectomy or segmentectomy for clinical stage I primary lung cancer (*N* = 11,531) was estimated for each of the providers. Surgeons were identified by their national provider identifier number (years 2009-2010) or surgeon name, national provider identifier when available, and participant number. Out of 11,531 study cases, surgeon information was missing for 350 operations (3%). Yearly study case volume of lobectomy or segmentectomy for clinical stage I primary lung cancer was averaged during the surgeon's activity period (or if the activity period was shorter than 6 months, estimated over the interval between case submission and data harvest date for the year in question, with 2 months as a minimum activity period). For incorporation into a multivariable analysis, the surgeons were divided into quartiles with the following annual volume distributions: ≥ 0.7 and <10 , ≥ 10 and <17 , ≥ 17 and <27 , and ≥ 27 and ≤ 70.2 .

A multivariable analysis was performed using patients with complete information (*n* = 8310) for 23 variables (use of mediastinal staging procedure, clinical T stage, age, gender, race, body mass index, predicted forced expiratory volume in 1 second, predicted diffusing capacity of carbon monoxide, year of surgery, clinical status at time of surgery, general thoracic reoperation, prior thoracic surgery, laterality, American Society of Anesthesiologists risk class, smoking status, Zubrod score, weight loss in 3 months before admission, hypertension, use of steroids, congestive heart failure, coronary artery disease, peripheral vascular disease, and renal insufficiency). A full list of data fields in the STS-GTD can be found at <http://www.sts.org/quality-research-patient-safety/national-database/data-base-managers/general-thoracic-surgery-databa-1>.

In an attempt to eliminate potentially confounding differences in the patient populations within the 2 cohorts, a propensity-matched analysis was performed as described in our previous publication using this dataset.⁵ A patient's propensity for having undergone a VATS procedure was determined by a logistic regression model using 23 preoperative patient characteristics as independent variables (see above multivariable description). The estimated probability of having undergone a VATS procedure was determined as a propensity score and used to match pairs of patients undergoing VATS and thoracotomy using a Greedy 5 to 1 digit algorithm,⁶ similar to the propensity strategy used in previous report from the STS-GTD.³ The majority of pairs had differences in propensity score <0.0001 and matched pairs were not formed if propensity score difference exceeded 0.1. The missing data for complications averaged 0.7% for the variables. There was no difference in the frequency of missing data for the complications by approach in the open and VATS cohorts, with the exception of discharge with chest tube, in which the data was missing in 1.1% of open and .5% of VATS patients (*P* < .001). The database analysis interprets a failure to indicate the presence of a complication as the absence of that particular complication.

RESULTS**Patients**

The patient and tumor attributes of the thoracotomy and VATS groups are listed in Table 1. Several important differences were identified, including a greater frequency of T1 tumors in the VATS cohort (76% vs 65%; *P* < .001) and better pulmonary function in VATS cohort (ie, predicted forced expiratory volume in 1 second of 83% vs 78%; *P* < .001). The VATS procedures were performed by surgeons that averaged more lobectomies for clinical stage I primary lung cancer each year (median, 20.4 vs 15.7 procedures per year; *P* < .001).

Multivariable Analysis of Complication Risk

Overall, 34% of patients experienced at least 1 complication. Patients undergoing thoracotomy were more likely to experience a complication (36.4%) than the VATS patients (28.9%) (*P* < .001). A multivariable analysis was performed to identify risk factors for the development of complications, and variables associated with a significant effect on complication risk are shown in Table 2. The VATS approach was associated with a lower risk of complications than thoracotomy (odds ratio, 0.775; 95% confidence interval, 0.702-0.856; *P* < .001). Increasing annual surgeon volume of lobectomy and segmentectomy for clinical stage I primary lung cancer was associated with a reduction in complication risk, with surgeons performing >27 per year having significantly fewer complications than surgeons performing <10 per year (odds ratio, 0.783; 95% confidence interval, 0.686-0.894; *P* < .001).

TABLE 1. Patient, tumor, and procedure characteristics

	Thoracotomy (n = 7137)	Video-assisted thoracic surgery (n = 4394)	P value
Clinical stage (%)			<.001
T1	64.6	76.1	
T2	35.4	23.9	
Extent of resection (n [%])			
Lobectomy	6667 (93.4)	1948 (92)*	
Segmentectomy	470 (6.6)	170 (8)*	
Estimated yearly surgeon volume* (median [interquartile range])	16.2 (9.1-27.2)	19.8 (12.3-28.9)	<.001
Age at time of surgery (y)			.032
Mean ± standard deviation	67.3 ± 10.3	67.9 ± 10.2	
Range	18-96	21-95	
Gender (%)			<.001
Female	50.6	56.8	
Race (%)			<.001
White	88.4	87.7	
Black	8.4	7.6	
Hispanic	1.6	2.0	
Asian	1.6	2.7	
Body mass index (%)			<.001
>35	10.3	8.3	
FEV1 (% predicted)			<.001
Mean ± standard deviation	78.5 ± 22	83 ± 22.8	
DLCO (% predicted)			<.001
Mean ± standard deviation	72.3 ± 22.7	75.2 ± 22.6	
Year of surgery (%)			<.001
2001-2004	12.6	3.1	
2005	9.1	3.5	
2006	11.2	8.1	
2007	12.2	13.7	
2008	15.7	19.8	
2009	26.9	34.1	
2010	12.3	17.7	
Clinical status (%)			<.001
Elective	95.3	98.2	
Urgent	3.5	.7	
Emergent	1.2	1.1	
General thoracic reoperation (%)			<.001
Yes	4.5	2.7	
Laterality of procedure (%)			.004
Right	57.4	60.2	
American Society of Anesthesiologists risk class (%)			<.001
I-II	18.4	24.2	
III	69.6	70.2	
IV-IV	12	5.6	

(Continued)

TABLE 1. Continued

	Thoracotomy (n = 7137)	Video-assisted thoracic surgery (n = 4394)	P value
Cigarette smoker (%)			.047
Ever	85.1	83.7	
Med staging procedure (%)†			<.001
Day of surgery or ≤45 d	69.4	80.3	

FEV1, Forced expiratory volume in 1 second; DLCO, carbon monoxide diffusing capacity. *Estimated surgeon volume was calculated by dividing the number of study cases (the 11,531 lobectomies and segmentectomies) performed by the surgeon over the time frame in which the surgeon submitted cases. †Med staging procedure includes mediastinoscopy, anterior mediastinoscopy, mediastinal lymph node biopsy, extended cervical mediastinoscopy, mediastinal lymph node dissection, mediastinal lymph node sampling, thoracoscopy diagnostic mediastinal space with biopsy, endobronchial ultrasound, and thoracic lymphadenectomy.

Outcomes Within Propensity-Matched Cohorts

To account for potentially confounding differences in the approach-stratified cohorts, a propensity analysis with matching was performed resulting in 2745 well-balanced matched pairs. Table 3 demonstrates that the VATS and thoracotomy cohorts were extremely well matched, with the exception of surgeon volume, which was not included in the propensity score.

The length of stay was shorter in the VATS cohort (mean, 5.6 ± 8.4 days for VATS vs 7.1 ± 7.0 days for thoracotomy; $P < .001$). Complication rates were higher in the thoracotomy cohort (36% vs 30%; $P < .001$) (Table 4). Operative mortality was not significantly different in the 2 groups (1.8 vs 1.3%; $P = .13$). Pulmonary complications were higher in the thoracotomy cohort (eg, pneumonia: 4.6% in the thoracotomy group and 3.4% in the VATS group), as were cardiovascular complications (eg, atrial fibrillation: 12.7% in thoracotomy patients and 9.7% in VATS patients) and the need for blood transfusion (6.2% in the thoracotomy group vs 4.0% in the VATS group).

Infectious complications were similar between the 2 cohorts (thoracotomy 3.6% vs VATS 3.0%; $P = .17$). Prolonged air leak was not different between the 2 groups (10.9% vs 10.7%) but discharge home with a chest tube was higher in the VATS cohort (8.4% VATS vs 5.9% thoracotomy; $P < .001$).

Readmissions were examined as a postoperative event. However readmissions within 30 days of surgery were not captured by the STS-GTD before 2009. Among propensity-matched cases, readmissions within 30 days of surgery were similar between the thoracotomy (81 out of 1386) and VATS (94 out of 1418) approaches (5.5% and 6.2%, respectively; $P = .42$). Because roughly half of the propensity-matched cases lacked this outcome variable (before 2009), we also examined readmissions in the unmatched groups. Among patients undergoing resection in

TABLE 2. Multivariable analysis (n = 8310) of risk to develop any postoperative complication

Characteristic	95%		P value
	Odds ratio	Confidence interval	
Approach (VATS vs open)	0.763	0.691-0.842	<.001
Average annual surgeon volume			
≥0.7 and <10*	1.00		<.001
≥10 and <17	0.967	0.848-1.104	
≥17 and <27	0.837	0.7270-0.964	
≥27 and ≤70.2	0.783	0.686-0.894	
Age at time of surgery	1.030	1.025-1.035	<.001
Race			
White*	1.00		.002
Black	0.718	0.599-0.860	
Hispanic	0.768	0.519-1.37	
Asian	0.923	0.640-1.332	
FEV1 (% predicted)	0.991	0.989-0.994	<.001
Thoracic reoperation (yes vs no)	1.656	1.317-2.081	<.001
American Society of Anesthesiologists risk class			
I-II*	1.00		<.001
III	1.319	1.155-1.507	
IV-V	1.641	1.363-1.976	
Cigarette smoking (ever vs never)	1.392	1.200-1.615	<.001
Zubrod score			
0 – normal activity*	1.000		
1 – symptoms by fully ambulatory	1.064	0.964-1.173	.001
2 – symptoms, in bed <50% of time	1.516	1.225-1.877	
3 – symptoms, in bed >50% but <100%	1.525	0.977-2.382	
Steroids (yes vs no)	1.489	1.182-1.877	.001
Peripheral vascular disease (yes vs no)	1.215	1.056-1.399	.007
Renal insufficiency (yes vs no)	1.636	1.264-2.118	<.001

VATS, Video-assisted thoracic surgery; FEV1, forced expiratory volume in 1 second.

*The risk of complications among subsequent subsets were compared with complications in the first subset.

2009 or later, readmissions within 30 days were similar between the thoracotomy (167 out of 2607) and VATS (149 out of 2156) cohorts (6.4% and 6.9%, respectively; $P = .52$).

Evaluation of Conversion Effect

It is possible that particularly complex VATS cases or those with intraoperative complications were converted to thoracotomy, thereby biasing outcome results against thoracotomy procedures. The STS-GTD does not contain a field to represent conversion per se; however, in both versions of the database there were indicators to determine if VATS and open procedures were performed on the same day (see the Methods section). A total of 1292 patients were coded as having a VATS approach procedure in addition to thoracotomy for lobectomy or segmentectomy (representing 18.1% of the thoracotomy cohort).

The more recent version of the database form (version 2.081) differentiates the secondary VATS procedures, which included most commonly diagnostic thoracoscopy

of lungs and pleura (57%), therapeutic wedge resection (22%), and thoracoscopy of mediastinal space (2%).

The use of both VATS and thoracotomy was not associated with a higher complication rate compared with thoracotomy alone (38.5% vs 35.9%; $P = .071$). However, the VATS cohort remained less likely to experience a complication, even when the combined approach cases (potentially containing converted cases) were excluded from the thoracotomy cohort (28.9% vs 35.9%; $P < .001$).

DISCUSSION

Overall, postoperative complications were reported in 34% of patients after lobectomy or segmentectomy for clinical stage I lung cancer in the STS-GTD. The database reflects the experience of Board-certified thoracic surgeons and the complication rates compare favorably to databases with more heterogeneous surgical representation. For example the Health Care Utilization Project reported a complication rate for lobectomy of 43%, whereas the Surveillance, Epidemiology, and End Results Medicare database reported a complication rate of 56% (Table 5). Similarly the operative mortality for early stage lung cancer in the STS-GTD (1.4%) appears considerably lower than databases containing surgeons with more diverse backgrounds (the Health Care Utilization Project 3.2% and Surveillance, Epidemiology, and End Results 3.6%).^{7,8}

The VATS approach to anatomic lung cancer resection was associated with significantly fewer complications than thoracotomy in STS-GTD, a finding that echoes reports from the National Surgical Quality Improvement Program,⁹ the Healthcare Utilization Project,¹⁰ as well as earlier studies from the STS-GTD^{3,11} (Table 5). Our study represents the largest study to date to evaluate treatment-associated morbidity in surgically managed, clinical stage I primary lung cancer.

The comprehensive classification of complications by the STS-GTD database has allowed the VATS effect on surgical morbidity to be more fully characterized. A reduction in pulmonary complications in the VATS cohort is perhaps the most intuitive, because of the reduction in chest wall and lung manipulation and postoperative pain. The finding that air leak prevalence was similar between VATS and thoracotomy cohorts (or perhaps even worse, because more VATS patients were discharged with a chest tube potentially representing an air leak) is a bit surprising. The proponents of VATS typically advocate a fissureless technique (thereby avoiding instrumentation of the fissure, a maneuver suspected of generating air leaks).¹² Possible explanations could be variable adherence to fissureless principles by VATS surgeons adopting the technique, or alternatively the use of the fissureless technique by surgeons performing lung cancer resections via thoracotomy. Finally, this could reflect a difference in surgeon comfort with patients being discharged with chest tubes.

Our study identified a significantly lower incidence of postoperative atrial fibrillation (25% fewer cases) when

TABLE 3. Patient, tumor, and procedure characteristics in propensity-matched cohorts

	Thoracotomy (n = 2745)	Video-assisted thoracic surgery (n = 2745)	P value
Clinical stage (%)			.67
T1	74.0	73.4	
T2	26.0	26.6	
Age at time of surgery (y)			.94
Mean ± standard deviation	68.1 ± 9.9	68.2 ± 10	
Estimated yearly surgeon volume* (median [interquartile range])	15.7 (9-26.6)	20.4 (12.5-29.2)	<.001
Gender (%)			.98
Female	54.2	54.2	
Race (%)			.90
White	88.9	89.3	
Black	7.5	7.5	
Hispanic	1.6	1.5	
Asian	2.0	1.7	
Body mass index (%)			.85
≤35	90.3	90.4	
>35	9.7	9.6	
FEV1 (% predicted)			.73
Mean ± standard deviation	81.3 ± 21.4	80.7 ± 22.3	
DLCO (% predicted)			.63
Mean ± standard deviation	73.5 ± 22.4	74.0 ± 22.3	
Year of surgery (%)			.97
2001-2004	2.7	2.4	
2005	3.8	3.4	
2006	7.9	8.1	
2007	11.8	12.1	
2008	16.7	16.4	
2009	38.4	38.2	
2010	18.7	19.4	
Clinical status (%)			.74
Elective	98.1	97.9	
Urgent	0.7	0.8	
Emergent	1.2	1.3	
General thoracic reoperation (%)			.27
Yes	3.8	3.2	
Prior thoracic surgery (%)			.71
Yes	12.3	12.0	
Laterality of procedure (%)			.76
Right	58.6	59.0	
American Society of Anesthesiologists risk class (%)			.98
I-II	18.7	18.8	
III	74.3	74.1	
IV-IV	7.0	7.1	
Cigarette smoker (%)			.49
Never	14.4	13.7	
Ever	85.6	86.3	

(Continued)

TABLE 3. Continued

	Thoracotomy (n = 2745)	Video-assisted thoracic surgery (n = 2745)	P value
Zubrod score			.45
0	46.9	47.2	
1	48.2	47.8	
2	3.9	4.3	
3	.8	.7	
4	.1	0	
Weight loss 3 mo before admission (kg)			.90
Mean ± standard deviation	0.6 ± 3.0	0.7 ± 3.6	
Hypertension (% yes)	66.3	66	.80
Steroid use (% yes)	3.7	3.6	.83
Congestive heart failure (% yes)	3.5	2.9	.25
Coronary artery disease (% yes)	22.7	22.7	.97
Peripheral vascular disease (% yes)	10.7	11.1	.63
Renal insufficiency (% yes)	2.9	2.5	.35

FEV1, Forced expiratory volume in 1 second; DLCO, carbon monoxide diffusing capacity. *Estimated surgeon volume was calculated by dividing the number of study cases (11,531 lobectomies and segmentectomies) performed by the surgeon over the time frame in which the surgeon submitted cases.

lung cancer was resected by VATS. This finding echoes a previous STS database study, but is contrary to other large institutional series.¹³ The implications of this reduction in atrial fibrillation are considerable, because the effect of perioperative atrial fibrillation on a patient's quality of life and overall health care expenditures is significant and extends beyond hospitalization.¹⁴

Readmissions in our study were similar to rates recently reported for lung cancer surgery.¹⁵ It is unclear why the readmissions did not differ by approach, but likely reflects a lack of difference in the types of complications that lead to readmission.

We explored the possibility that the lower complication rates in the VATS cohort were secondary to greater surgical experience among the surgeons performing VATS procedures. We did in fact find that the VATS procedures were done by surgeons with a greater annual volume (median, 20.4 cases per year for VATS vs 15.7 cases for thoracotomy). However, a multivariable analysis demonstrated that the effect of approach (VATS having fewer complications) remained significant when adjusting for differences in volume. Therefore, the thoracotomy approach appears to be an independent risk factor for complications in patients with clinical stage I cancer.

It was not possible to determine which patients were converted from VATS to thoracotomy, which has the potential to bias against the outcomes of the thoracotomy group. Although it is encouraging that complication rates

GTS

TABLE 4. Complications by surgical approach in propensity-matched cases

	Thoracotomy (n = 2745)	Video-assisted thoracic surgery (n = 2745)	P value
Operative times (min)			<.001
Median (interquartile range)	145 (109-196)	173 (128-220)	
Length of stay (median d)	5	4	<.001
Interquartile range	(4-8)	(3-6)	
Length of stay >14 d* (%)	7.4	4.3	<.001
Operative mortality (hospital or 30-d) (%)	1.8	1.3	.12
Readmission within 30 d of surgery (%)†	5.5	6.2	.42
Any complication (%)	36.2	29.9	<.001
Any pulmonary complication (%)	20.8	18.3	.017
Air leak >5 d postoperation	10.9	10.7	.90
Patient discharged with chest tube	5.9	8.4	<.001
Atelectasis requiring bronchoscopy	4.1	2.7	.005
Pneumonia	4.6	3.4	.033
Adult respiratory distress	1.1	0.5	.006
Bronchopleural fistula	0.3	0.3	1
Pulmonary embolus	0.4	0.3	.51
Initial vent support >48 h	0.8	0.4	.076
Reintubation	4.3	2.8	.003
Tracheostomy	1.2	1	.51
Any cardiovascular complication (%)	15	11.3	<.001
Atrial arrhythmia requiring treatment	12.7	9.7	<.001
Ventricular arrhythmia requiring treatment	0.9	0.5	.057
Myocardial infarction	0.3	.2	.44
Deep vein thrombosis requiring treatment	0.5	0.4	.84
Any hematology complication (%)	8.6	5.4	<.001
Bleeding requiring reoperation	1.1	1.3	.46
Blood transfusion intraoperatively	2.8	1.1	<.001
Blood transfusion postoperatively	6.2	4	<.001
Any infectious complication (%)	3.6	3	.17
Urinary tract infection	2.1	2	.70
Empyema requiring treatment	0.6	0.3	.041
Wound infection	0.4	0.4	.83
Sepsis	0.9	0.4	.013
Any neurologic complication (%)	3.7	2.3	.003

(Continued)

TABLE 4. Continued

	Thoracotomy (n = 2745)	Video-assisted thoracic surgery (n = 2745)	P value
New central neurologic event	0.7	0.4	.19
Recurrent laryngeal nerve paresis	0.3	0.1	.058
Delirium	2	1.3	.045
New renal failure or creatinine ≥2× preoperative (%)	2	1.1	.006

*>14 days was defined as prolonged length of stay by previous Society of Thoracic Surgeons analysis.¹⁶ †Only patients undergoing surgery during 2009 or later are included in this analysis because the variable was not captured in the Society of Thoracic Surgeons-General Thoracic Database before 2009.

remained lower in the VATS cohort despite the exclusion of cases with multiple approaches listed, without a specific conversion data field it is not possible to distinguish conversions from true diagnostic procedures before a planned thoracotomy.

Limitations

The principle limitations include a potential for selection bias for cases submitted to the database, because participation is voluntary. In addition, it is possible that patients undergoing VATS were healthier in ways not captured by the database. The database cannot distinguish conversions from VATS to thoracotomy; therefore, these particularly challenging cases would be coded in the thoracotomy group. The differences in atrial fibrillation prevalence and other complications may reflect other aspects of perioperative management unrelated to surgical approach (such as use of perioperative beta blockers or improved pulmonary toilet). We attempted to exclude surgeon volume as a confounder of the approach effects. The effect of approach on complications remained independent of volume effects in multivariable analysis. However, we only considered volume within the case series (11,531 clinical stage I lobectomies and segmentectomies), and therefore we may have underestimated the surgical experience of surgeons who perform significant numbers of resections for more advanced primary lung cancer (clinical stage II or III) or benign disease. We also did not separate surgeon case volume into VATS from thoracotomy annual experience, recognizing the possibility that the importance of approach-specific experience may be missed.

CONCLUSIONS

Postoperative complications are less common following anatomic resection of clinical stage I lung cancer performed by Board-certified thoracic surgeons using the VATS approach instead of thoracotomy. This should be taken into consideration when counseling patients for surgery.

TABLE 5. Comparison of complications by approach for lobectomy or segmentectomy for lung cancer in the literature

Database	Total complications	Thoracotomy	Video-assisted thoracic surgery	P value*
Healthcare Utilization Project-National Inpatient Sample ¹⁰	2657/6292 (42.2)	2074/4769 (43.5)	583/1523 (38.3)	<.001
American College of Surgeons National Surgical Quality Improvement Program ⁹	496/2353 (21.1)†	412/1737 (23.7)†	84/616 (13.6)†	<.001
Surveillance, Epidemiology, and End Results ⁸	2329/4171 (55.8)	NA	NA	NA
Society of Thoracic Surgeons previous report – all stages‡,3	780/2562 (30.4)	444/1281 (34.7)	336/1281 (26.2)	<.001
Society of Thoracic Surgeons current report – clinical stage I‡	1816/5490 (33.1)	994/2745 (36.2)	822/2745 (29.9)	<.001

Data are presented as n (%). NA, Not available. *Between thoracotomy and video-assisted thoracic surgery. †Atrial fibrillation not included. ‡Propensity-matched cohorts.

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