Original Article

Lung lobectomy surgical approach and resource utilization differ by anatomic lobe in a statewide discharge registry

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Background: Anatomic lobe-specific differences with respect to pulmonary lobectomy have been suggested in the thoracic surgery literature but hard data has been lacking in larger population studies in part due to coding systems that do not distinguish pulmonary lobectomy by anatomic lobe. International Classification of Diseases, Tenth Revision (ICD-10) procedure codes, adopted in the United States in 2015, may provide novel methodologic accessibility for pulmonary lobectomy studies as they classify lobectomy operations by specific anatomic lobe. We queried the Texas Inpatient Public Use Data File (TPUDF) ICD-10 codes for both open and endoscopic approach lobectomy with a specific view to differences based on anatomic lobes.

Methods: Between fourth fiscal quarter (Q4) 2015 and Q4 2017, all pulmonary lobectomy operations performed in Texas state-licensed hospitals were identified by querying the TPUDF for ICD-10 procedure codes for pulmonary lobectomy as classified by anatomic lobe. Surgical approach, additional procedures and diagnosis codes, length of hospital stay (LOS), and discharge status were recorded with aggregate values undergoing statistical analysis.

Results: Right and left upper versus lower lobe resections were more prevalent however minimally invasive surgery was less commonly performed for upper than right lower lobectomy. LOS, irrespective of surgical approach, was longer for upper versus lower lobe resection as was need for transfer to additional inpatient facilities. LOS was longer and need for additional surgical or procedural interventions days after the primary procedure of lobectomy was greater for right versus left upper lobe resection, suggesting some differential properties of the right versus left pleural space.

Conclusions: The marked clinical differences between anatomic lobes in the setting of pulmonary lobectomy observed in this study have the potential to translate to differences in expected hospital and health system costs and surgeon time-expenditure and experience premium that currently have no mechanism for their accounting. These findings highlight the value of ICD-10 coding for analysis of pulmonary lobectomy in administrative databases and suggest a possible path to more informed patient counseling and equitable hospital and surgeon reimbursement based on payment adjustment by anatomic lobe in pulmonary lobectomy operations.

Keywords: Pulmonary lobectomy; lung cancer; lung cancer surgery; administrative healthcare databases

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Introduction

Pulmonary lobectomy is the most common major non-cardiac thoracic operation and lobectomy outcomes serve as a Society of Thoracic Surgeons (STS) General Thoracic Surgery Database (GTSD) quality benchmark (1). For coding or quality assurance purposes lobectomy operations are not distinguished by anatomic lobe in terms of risk of patient complications, surgeon labor or expertise, or hospital length of stay and/or cost. For example, upper *vs.* lower or right sided *vs.* left sided lobe does not factor into lobectomy coding for surgeon fee or hospital reimbursement. However, lobe-specific technical considerations or risks of post-operative complication have been mentioned or suggested in the thoracic surgery literature. Upper lobe resection has been identified as an independent risk factor for prolonged air leak (2). Left and right upper lobe resection by thoracoscopy have merited special focus with respect to technical aspects and/or have been cited as higher risk for intra-operative technical pitfalls compared to other anatomic lobectomy (3-5). However, hard data is lacking. These considerations could impact patient outcomes and health system costs downstream but evidence-backed studies of anatomic lobe-dependent outcomes in lobectomy have been hampered in part by coding systems that do not facilitate analysis of pulmonary lobectomy by anatomic lobe in large population databases.

Health care administrative databases, despite lacking thoracic surgery-specific patient data, have informed numerous outcomes studies in thoracic surgery and may provide novel methodologic accessibility for pulmonary lobectomy studies through the recent adoption, in the fourth fiscal quarter (Q4) 2015 in the United States, of International Classification of Diseases, Tenth Revision (ICD-10) procedure codes, which distinguish lobectomy operations by specific anatomic lobe for both open and endoscopic approaches (6). We queried the Texas administrative registry of inpatient hospital discharges using ICD-10 codes for both open and endoscopic approach lobectomy with a specific view to differences based on anatomic lobes. We present the following article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-21-1898/rc).

Methods

The Texas Inpatient Public Use Data File (TPUDF), maintained by the Texas Department of State Health Services (TDSHS), captures nearly 100% of hospitalizations from all Texas state-licensed hospitals (excluding federal and small, statutorily exempt hospitals) (7). Individual hospitals are responsible for the accuracy and completeness of their data and records are audited by TDSHS for consistency and conformity. Mortality, recorded as "expired" status at discharge, reflects only in-hospital mortality; mortality after discharge or 30-day mortality are not recorded. Patient age is recorded in coding ranges. Hospitals with fewer than 50 discharges are not identified by name to preserve patient and physician confidentiality. A Data Use Agreement was obtained from the TDSHS for access to the TPUDF. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

ICD-10-PCS codes categorize lobectomy operations by anatomic lobe and by "open" or "percutaneous endoscopic approach" (PEA) and include the left lung lingula as a lobe of the lung (6). The following codes designate lobectomy operations in ICD-10-PCS: 0BTC0ZZ Resection of Right Upper Lung Lobe, Open Approach; 0BTC4ZZ Resection of Right Upper Lung Lobe, Percutaneous Endoscopic Approach; 0BTD0ZZ Resection of Right Middle Lung Lobe, Open Approach; 0BTD4ZZ Resection of Right Middle Lung Lobe, Percutaneous Endoscopic Approach; 0BTF0ZZ Resection of Right Lower Lung Lobe, Open Approach; 0BTF4ZZ Resection of Right Lower Lung Lobe, Percutaneous Endoscopic Approach; 0BTG0ZZ Resection of Left Upper Lung Lobe, Open Approach; 0BTG4ZZ Resection of Left Upper Lung Lobe, Percutaneous Endoscopic Approach; 0BTH0ZZ Resection of Lung Lingula, Open Approach; 0BTH4ZZ Resection of Lung Lingula, Percutaneous Endoscopic Approach; 0BTJ0ZZ Resection of Left Lower Lung Lobe, Open Approach; 0BTJ4ZZ Resection of Left Lower Lung Lobe, Percutaneous Endoscopic Approach.

All cases in which one of the above listed ICD-10-PCS lobectomy codes was entered in the TPUDF as "the principal surgical or other procedure performed during the period covered by the bill" for an inpatient discharge were identified by searching TPUDF data field 103 (and date of procedure from data field 104) for the period of Q4 2015-Q4 2017. Patient data from these discharges were gathered and analyzed for sub-population differences. Patients with age-code indicating <18 years of age were excluded. Hospitals performing <10 lobectomy operations over the study period were considered low-volume outliers and lobectomy operations from these

Table 1 Lobectomy population demographics

Characteristic	Value
N	3,297
Gender (%)	
Male	46.5
Female	53.5
Average patient age (years)	65–69
ICD-10-CM lung cancer diagnosis (%)	80
Discharge status (%)	
Expired	1.7
Home or self-care	76
Home health	13
Subsequent inpatient facility	9
Court/law enforcement	0.4
Left against medical advice	0.2
Hospice	0.2

ICD-10-CM, International Classification of Diseases, tenth revision, Clinical Modification.

hospitals were excluded from analysis. Diagnosis codes associated with the lobectomy admission were searched in TPUDF data fields 32-102 with special attention to ICD-10 Clinical Modification (ICD-10-CM) codes for lung cancer (C34.00-C34.92) (6) in data fields 32, "Admitting Diagnosis", and 33, "Principal Diagnosis Code". Gender is suppressed and age range separately scaled in the TPUDF in cases where ICD-10-CM coding indicates drug or alcohol use or human immunodeficiency virus (HIV) diagnosis, therefore these patients (n=144) were excluded from analysis. Procedures recorded as having been performed on a date after the date of the primary procedure were identified by searching procedure codes and dates of procedure in TPUDF data fields 105-152.

The first objective was to record the prevalence by anatomic lobe of open and PEA approach lobectomy in the overall lobectomy population as well as the prevalence of lung cancer. The next objective was to compare PEA *vs.* open approach percentages for each anatomic lobe to identify differences in choice or limitation of surgical approach by anatomic lobe. We next sought to determine differences in length of stay (LOS) and "expired" status at discharge between anatomic lobes by different surgical approach as surrogates for post-operative resource utilization/complications and 30-day mortality respectively. We then searched in the 23 data fields for "surgical or other procedure other than the principal procedure performed during the period covered by the bill" for procedures listed as having occurred on a later date than that of the principal procedure as an indicator of increased post-operative resource utilization and as a surrogate for post-operative complications. Finally, we looked at discharge status to identify lobectomy patients broken down by anatomic lobe and surgical approach who required transfer to a subsequent inpatient facility such as a skilled nursing facility (SNF) *vs.* discharge to home/self-care. We studiously avoided comparisons of open *vs.* PEA approaches and focused only on open *vs.* open, PEA *vs.* PEA, or all (open + PEA) *vs.* all lobectomy approaches for statistical analysis in an attempt to minimize possible confounding factors based on differences in surgical approach.

Statistical analysis

For observed *vs.* expected comparisons, chi-square testing for categorical variables was employed. For continuous variables, mean values were reported with standard deviations and compared by two-tailed *t*-test. All statistical testing employed a significance level of 0.05.

Results

Between Q4 2015–Q4 2017, 87 hospitals met the inclusion criterion of >/=10 lobectomy operations during the study period performing a combined total of 3,297 lobectomy operations with median number of operations per hospital of 23 (range, 10–324). (Seventy-five programs performing a combined total of 267 lobectomy operations were excluded as low volume outliers as per description in Methods). The lobectomy population demographics are presented in *Table 1*. For the 3,297 lobectomies, patient sex was female 53.5%, male 46.5%, and average patient age was in the 65–69 years-of-age coding range. ICD-10-CM coding for lung cancer was present in 2,643/3,297 (80%) of patient records. Median LOS was 6 days (mean 7.0±6.1 days). "Expired" status at discharge was recorded in 56/3,297 (1.7%) cases. Other patient discharge status was: "Discharged to home or self-care": 2,493/3,297 (76%); "Discharged/transferred to home under care of an organized home health service organization": 420/3,297 (13%); discharge/transfer to a subsequent inpatient facility or status ("short-term general hospital", "skilled nursing

Table 2 Overall distribution of resected anatomic lobe (open + PEA combined)

Anatomic lobe (open + PEA)	Number (percent of total) (total=3,297)	P value
RUL	1,033 (31%)	P<0.0001 *vs.* RLL
RML	278 (8%)	–
RLL	692 (21%)	–
LUL	763 (23%)	P<0.0001 *vs.* LLL
Lingula	10 (<1%)	–
LLL	521 (16%)	–

PEA, percutaneous endoscopic approach; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

Table 3 Distribution by anatomic lobe for lobectomy performed by PEA

PEA resection by lobe	Total: 1,440/3,297 (44%)	P value
RUL	442/1,033 (43%)	P=0.048 *vs.* RLL
RML	126/278 (45%)	P=0.523 *vs.* RLL
RLL	330/692 (48%)	–
LUL	315/763 (41%)	P=0.015 *vs.* RLL
Lingula	4/10 (40%)	P=0.755 *vs.* RLL
LLL	223/521 (43%)	P=0.092 *vs.* RLL

PEA, percutaneous endoscopic approach; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

facility (SNF)", "custodial or supportive care", "Medicare-approved swing bed", "inpatient rehabilitation", "long-term care"): 301/3,297 (9%); "Discharged/transferred to Court/Law Enforcement": 15/3,297 (0.4%); left against medical advice: 7/3,297 (0.2%); hospice: 5/3,297 (0.2%).

Right upper lobe was the most commonly resected lobe [1,033/3,297 (31%)] followed by left upper lobe [763/3,297 (23%)], right lower lobe [692/3,297 (21%)], left lower lobe [521/3,297 (16%)], right middle lobe [278/3,297 (8%)], and lingula [10/3,297 (<1%)]. Assuming lung pathology requiring lobectomy would be expected to occur with equal likelihood based solely on normal lobar volume distribution, the observed rates of lobar resection differed significantly from expected. Lobar anatomic volume distribution calculated from chest computed tomography imaging in normal subjects has been reported recently with percentage volume distribution as follows: right upper 18.2%, right middle 8.2%, right lower 26.7%, left upper 23%, left lower 23.9% (8). With reference to these values, a higher frequency of right upper lobe *vs.* right lower lobe resection (P<0.0001) and of left upper lobe *vs.* left lower lobe resection (P<0.0001) was observed *vs.* expected (*Table 2*).

Operations were designated "percutaneous endoscopic approach" (PEA) in 1,440/3,297 (44%) of cases *vs.* 1,857/3,297 (56%) open. PEA lobectomy by anatomic lobar distribution was as follows: right upper 442/1,033 (43%), right middle 126/278 (45%), right lower 330/692 (48%), left upper 315/763 (41%), left lower 223/521 (43%), lingula 4/10 (40%). There was a higher frequency of right lower lobe resection by PEA compared to right upper lobe (48% *vs.* 43%, P=0.048) and left upper lobe (48% *vs.* 41%, P=0.015). No statistical difference between right lower lobectomy *vs.* left lower lobectomy PEA frequency was observed (48% *vs.* 43%, P=0.092) (*Table 3*).

Mean LOS was greater for open RUL *vs.* RLL resection (9.01±7.59 *vs.* 7.58±5.22 days, P=0.0016), PEA RUL *vs.* RLL resection (6.24±7.97 *vs.* 4.90±3.86 days, P=0.005), and all (open + PEA) RUL *vs.* RLL resection (7.82±7.87 *vs.* 6.30±4.81 days, P<0.0001) (*Table 4*). Mean LOS was not statistically different for open LUL *vs.* LLL resection (8.04±5.03 *vs.* 7.36±5.62 days, P=0.0.080) or PEA LUL *vs.*

Table 4 Length of stay for lobectomy broken down by anatomic lobe and open versus PEA surgical approach

Lobe and approach	Length of stay (days ± SD)	P value
Open		
RUL	9.01±7.59	P=0.0016 *vs.* open RLL
RML	7.74±6.49	–
RLL	7.58±5.22	–
LUL	8.04±5.03	P=0.080 *vs.* open LLL
Lingula	6.17±4.07	–
LLL	7.36±5.62	–
PEA		
RUL	6.24±7.97	P=0.005 *vs.* PEA RLL
RML	5.05±4.02	–
RLL	4.90±3.86	–
LUL	5.45±3.94	P=0.142 *vs.* PEA LLL
Lingula	2.75±0.96	–
LLL	4.89±4.88	–
All (open + PEA)		
RUL	7.82±7.87	P<0.0001 *vs.* all RLL; P=0.0082 *vs.* all LUL
RML	6.51±5.66	–
RLL	6.30±4.81	–
LUL	6.97±4.78	P=0.020 *vs.* all LLL
Lingula	4.80±3.55	–
LLL	6.3±5.45	–

PEA, percutaneous endoscopic approach; SD, standard deviation; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

LLL resection (5.45±3.94 *vs.* 4.89±4.88 days, P=0.142) but was statistically different for all (open + PEA) LUL *vs.* LLL resection (6.97±4.78 *vs.* 6.3±5.45 days, P=0.020) (*Table 4*). Mean LOS was greater for all (open + PEA) RUL *vs.* LUL resection (7.82±7.87 *vs.* 6.97±4.78 days, P=0.0082) (*Table 4*). "Expired" status at discharge was not statistically different for RUL *vs.* RLL (open + PEA) (2.0% *vs.* 1.7%, P=0.7225) or LUL *vs.* LLL (open + PEA) resection [1.0% *vs.* 2.3% (P=0.11)].

In the 23 data fields for "surgical or other procedure other than the principal procedure performed during the period covered by the bill", in 399/3,297 lobectomy patients (12%) a procedure code was recorded with a procedure date of a later date than that of the principal procedure. Mean LOS for these patients was 11.6±8.8 days (P<0.0001 *vs.* total lobectomy cohort), "expired" discharge status was 31/399 (8%, P<0.0001 *vs.* total lobectomy cohort). Open (276/399, 69%) *vs.* PEA (123/399, 31%) lobectomy patients were over-represented in this cohort *vs.* the total population distribution of open (1,857/3,297, 56%) *vs.* PEA lobectomy (1,440/3,297, 44%) (P<0.0001). For open right upper lobectomy there was a higher observed rate of procedure(s) of a later date than the primary procedure *vs.* expected based on the prevalence of open right upper lobe resection in the overall open cohort [107/276 (39%) *vs.* 591/1,857 (32%), P=0.023]. Additionally, for all (open + PEA) right upper lobectomy there was a higher observed rate of procedure(s) of a later date than the primary procedure *vs.* expected based on the prevalence of upper lobe resection in the overall "all" (open + PEA) cohort [148/399 (37%) *vs.*

Table 5 Need for additional procedures of a date subsequent to the lobectomy operation broken down by anatomic lobe and open *vs.* PEA surgical approach

Anatomic lobe	Need for additional procedure number (percentage)	P value versus open, PEA or open + PEA cohort
Open (n=276)		
RUL	107 (39%)	P=0.023
RML	15 (5%)	P=0.119
RLL	46 (17%)	P=0.287
LUL	65 (24%)	P=0.880
Lingula	0 (0%)	NA
LLL	43 (16%)	P=0.930
PEA (n=123)		
RUL	41 (33%)	P=0.540
RML	12 (10%)	P=0.740
RLL	31 (25%)	P=0.578
LUL	26 (21%)	P=0.910
Lingula	0 (0%)	NA
LLL	13 (10%)	P=0.188
All (open + PEA) (n=399)		
RUL	148 (37%)	P=0.023
RML	27 (7%)	P=0.289
RLL	77 (19%)	P=0.473
LUL	91 (23%)	P=0.950
Lingula	0 (0%)	NA
LLL	56 (14%)	P=0.382

PEA, percutaneous endoscopic approach; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

1,033/3,297 (31%), P=0.023]. This pattern did not hold for PEA right upper lobectomy alone [41/123, 33% (P=0.540)] or for any other anatomic lobectomy open, PEA, or all (open + PEA) (*Table 5*).

Patients with discharge status of discharge/transfer to a subsequent inpatient facility (e.g., SNF) (n=307) consisted of 87 patients with PEA lobectomy (28%) and 220 patients with open lobectomy (72%). Open *vs.* PEA resection patients were disproportionately represented in this discharge status *vs.* the overall cohort of 1,857/3,297 (56%) open *vs.* 1,440/3,297 (44%) PEA (P<0.0001). Lobar distribution for open resection patients with this discharge status (n=220) was as follows: right upper 78/220 (35%); right middle 16/220 (7%); right lower 39/220 (18%); left upper 59/220 (27%); lingula 1/220 (0.5%); left lower 27/220 (12%). There was a higher observed rate of upper (RUL + LUL) *vs.* lower (RLL + LLL) open lobe resection patients with discharge/transfer to a subsequent inpatient facility than expected based on upper *vs.* lower lobar anatomic distribution within the overall cohort [137/220 (62%) *vs.* 1,769/3,297 (54%), P=0.028]; this pattern did not extend to upper *vs.* lower lobe PEA resection patients [47/87 (54%) *vs.* 1,769/3,297 (54%), P=0.7634].

Twenty of 87 lobectomy hospitals were designated "high upper lobe PEA" based on both right and left upper lobectomy being performed by PEA in >/=50% of cases. For these programs the overall median LOS for all lobectomy (open + PEA, all anatomic lobes) was 4 days (mean

5.9±6.2 days) which was significantly less than for low upper lobe PEA hospitals (67/87 hospitals) with overall median LOS for all lobectomy (open + PEA, all anatomic lobes) of 6 days (mean 7.74±6.0 days, P<0.0001). “Expired” status at discharge for high upper lobe PEA for all lobectomy was recorded in 17/1,395 (1.2%) cases *vs.* 39/1,902 (2.0%) for low upper lobe PEA hospitals all lobectomy which was not statistically significant (P=0.068).

Six of the 15 highest volume lobectomy programs in the cohort of the 87 lobectomy hospitals examined performed less than 50% of their lobectomy operations by PEA. Fourteen of the 87 lobectomy programs performed 0% of lobectomy by PEA.

Discussion

This study represents an early effort at extracting pulmonary lobectomy data from an administrative database using ICD-10. For clarity, the ICD-10-PCS term, “PEA”, maps to thoracoscopic or VATS (though coding misclassification may occur as we discuss below) while the term, “open”, maps to thoracotomy, therefore in this discussion the term “PEA” will be used interchangeably with thoracoscopic or VATS and “open” will be used interchangeably with thoracotomy. A brief summation of the statistically significant findings of this study is as follows. Right upper lobe resection was performed more commonly than right lower lobe resection as was left upper *vs.* left lower lobe resection. Right lower lobe resection was performed by a VATS approach with greater frequency than right upper or left upper lobe resection. The length of hospital stay was greater for right upper lobe *vs.* right lower lobe resection either by thoracotomy or VATS approaches. The length of stay for left upper lobe *vs.* left lower lobe resection was greater for thoracotomy but for not for VATS approach. A longer length of stay was observed for all (open + VATS approach) right upper lobe *vs.* left upper lobe resection. The performance of additional interventions or procedures on a day subsequent to the lobectomy operation was greater for open and all (open + VATS) right upper lobe resection than would have been expected given the prevalence of right upper lobe resection in the overall lobectomy population which did not hold true for any other anatomic lobe. There was a higher observed rate of upper (RUL + LUL) *vs.* lower (RLL + LLL) open lobe resection patients with discharge/transfer to a subsequent inpatient facility (e.g., SNF) than expected based on upper *vs.* lower lobar anatomic distribution within the overall cohort; this pattern did not hold for upper *vs.* lower lobe PEA resection patients.

We feel several insights were gleaned that were specific to the methodologic advantages of this approach. First, right lower lobectomy was statistically more frequently performed by thoracoscopy than either right or left upper lobectomy (*Table 3*). Right lower lobectomy may be viewed as the most anatomically straightforward lobectomy—in our program right lower lobectomy is consistently performed with the shortest operative times—but we did not expect to observe such a statistically significant difference in thoracoscopic adoption rate between anatomic lobes across the TPUDF population. We are not aware of prior studies revealing this pattern. We were initially concerned that the TPUDF might be overly biased by the surgical results of lower-volume or low-thoracoscopy adoption cardiothoracic surgery programs that were either choosing not to perform or were not capable of performing thoracoscopic upper and lower lobe resection with equal application. The overall VATS lobectomy rate of 44% was low but as noted in the results many hospitals in our state as recently as 2017 performed low rates of VATS lobectomy and some performed no VATS lobectomy. However, the TPUDF did permit inter-lobar differences in lobectomy surgical approach to be in fact detectable at all and on closer examination these differences fell out along clinically meaningful lines. VATS lobectomy is considered technically demanding (9) and many consider left and right upper lobe resection, particularly by VATS, to be more difficult due to more variable anatomy (3,4), so technical limitations could underlie the lower rates of thoracoscopic upper lobe resection seen in the TPUDF. As noted elsewhere in the results, 20/87 hospitals in this study, generally higher volume centers (median 56 lobectomy operations over the study period), reported PEA lobectomy rates for right and left upper lobe of >/=50%. This suggested technical focus or expertise in operations labelled PEA lobectomy, specifically upper lobectomy, predominantly expressed in some higher volume hospitals which, again, to our knowledge had not been previously clearly documented in the literature. Pathology that would have represented a relative or absolute contraindication to a PEA approach such as a tendency to larger or more central tumors, more advanced nodal disease, tumor chest wall invasion (10) or other factors or bias favoring one or more anatomic pulmonary lobes not discernable from the TPUDF data was also a possible explanation for the difference between thoracoscopic adoption between anatomic lobes.

Furthermore, the TPUDF data, and ICD-10-PCS coding generally, do not allow a determination of whether PEA lobectomy had been attempted and converted to open or not attempted at all. We conclude that searching ICD-10 in administrative databases has value and that the ability to gather information regarding broad patterns in surgical-approach choice or adoption among diverse hospitals may be a strength of this methodology. In administrative databases, while clinical data may be limited, coding for surgical approach should be consistently available and relatively high-fidelity as it hinges on hospitals' coding for their own billing (11).

We view left and right lower lobectomy as similarly anatomically straightforward however a difference between left lower lobe and any upper lobe minimally invasive surgery rates was not observed with statistical significance (*Table 3*). A trend toward a lower likelihood of thoracoscopic approach to left *vs.* right lower lobectomy was noted, (*Table 3*) which may be understood by inherent difficulties of left lower lobe anatomic access. Our program approaches thoracoscopic lobectomy by an anterior-to-posterior dissection (12). Our experience with this approach is that access to left lower lobe hilar structures may be limited as previously described for left lower lobe resection via median sternotomy, by a high left hemi-diaphragm in obese patients and/or by cardiomegaly (13). A high diaphragm on either left or right can be mitigated by a suture placed through the central tendon of the diaphragm retracting the diaphragm via the more caudally placed thoracoscopic camera port. A low posterior thoracoscopy port can also be added to facilitate access to the inferior pulmonary vein by a posterior approach in cases of cardiomegaly obstructing anteriorly introduced instruments. These maneuvers almost always allow adequate anatomic exposure, in our experience, to accomplish thoracoscopic left lower lobectomy, however, poorer access to left lower lobe hilar structures may underlie the lower thoracoscopy approach rate observed in this study.

In the authors' opinion, both right and left upper lobe resection pose greater intraoperative hazard than lower lobe resection due more variable anatomy and risk of injury that could necessitate pneumonectomy. The practice of our program is heavily weighted toward thoracoscopy (via anterior-to-posterior approach) for right and left upper lobe resection due to improved pain control and respiratory recovery and shorter hospital length of stay. For right upper lobe resection our dissection begins with isolation and prompt sequential division of right upper lobe vein and anterior-apical trunk artery using the surgical stapler. The dissection proceeds over the superior aspect of the hilum and posteriorly as far as can be accessed with the upper lobe retracted caudally making use of the 30-degree thoracoscopic camera to avoid repeated re-positioning of the lung. The camera is then returned to an anterior-to-posterior orientation and the upper lobe bronchus dissection completed by removal of level 11R lymph nodes. Minor fissure division may precede upper lobe bronchial division if this facilitates establishment of a more secure bronchial stump. Unless it would compromise the completeness of the lymphadenectomy, in some cases we forgo individual dissection and division of all segmental arteries arising distally to the anterior-apical trunk instead dividing these within the minor fissure staple line, which reduces potential bleeding and operative time. Clear and repeated visualization of the main trunk artery extending to the middle and lower lobes, the middle lobe vein, and the bronchus intermedius are crucial to avoiding intra-operative misadventure or compromised post-operative function of the middle and lower lobes. The minor fissure, though usually incomplete, can usually be established effectively and expeditiously by positioning the parenchymal stapler between the middle and upper lobe veins and directing the minor fissure staple line toward the posterior minor fissural cleft, which is almost always present. We always perform a pexy of the middle lobe to the lower lobe after removal of the upper lobe specimen to prevent middle lobe torsion. For left upper lobe resection by thoracoscopy the actions are essentially the mirror image of the right upper lobe though isolation of the upper lobe bronchus does not require the division of additional segmental arteries due to its more anterior location in the hilum. As with left lower lobectomy, a posterior thoracoscopic access incision may be added if the surgical stapler cannot pass freely around left upper lobe hilar structures without undue torque or obstruction. As with right upper lobe resection, small segmental arteries may be divided along with the fissure staple line.

The data in this study further supports the notion that right upper lobe resection, regardless of surgical approach, carries with it more hazard of a longer LOS and higher post-operative resource utilization than any other lobe resection. In this study, all (open + PEA) right upper lobectomy LOS was statistically longer than for any other anatomic lobectomy including all (open + PEA) left upper lobe, a finding that came out of our efforts to compare only like-to-like surgical approaches and avoid comparisons of open *vs.* minimally invasive approaches (*Table 3*). Prolonged

LOS as a study surrogate for post-operative complications is limited in that not all programs or payors share the same focus on reducing LOS (14), but this caution seems less relevant when comparing LOS across a large breadth of thoracic surgery hospitals in their post-operative management of specific anatomic pulmonary lobectomy and suggests a deeper clinical explanation. Along with the greater LOS, the need for procedures or operations of a date later than the initial lobectomy operation was statistically higher for all (open + PEA) right upper lobectomy than would be expected based on the prevalence of right upper lobectomy in the overall population, again entailing increased inpatient resource utilization and hospital cost (*Table 5*). This did not hold true for left upper lobectomy (*Table 5*). A previous study found upper lobe resection to be an independent risk factor for prolonged air leak suggesting a possible causative element in prolonged LOS and need for additional procedures or operations but that study did not identify differential risk in right *vs.* left upper lobe (2). We investigated some of the additional procedures in the right upper lobe cohort by their ICD-10-PCS codes, many of which were unfamiliar to us by their wording and which we could not in all cases clearly map to operations we code for in Current Procedural Terminology (CPT) codes. In some cases, additional procedures appeared to represent interventions, such as central venous line placement, that would not be likely in and of themselves to prolong LOS but suggested an underlying complication or comorbidity that might have led to prolonged LOS, such as atrial fibrillation or deep venous thrombosis. In other cases, some form of pleural procedure was indicated by the ICD-10-PCS code which might have implied not only an underlying condition, for example, prolonged air leak or empyema, but also recovery from additional surgical intervention requiring general anesthesia which could have prolonged LOS. However, lacking more detailed thoracic surgery-specific clinical parameters in this administrative database data and clearer ICD-10 procedure code-mapping to CPT codes other lobe-specific pathology or study bias could not be excluded. The finding of greater inpatient resource utilization by right upper lobectomy of any approach may fall to a greater likelihood of persistent post-resection space, long recognized as a potential source of serious complications (15). The right pleural space houses the larger lung (8) and the presence of the liver below the right hemi-diaphragm renders it less mobile than the left, conditions which may lead to a right pleural space less able to accommodate a post-resection lung-to-pleura size mismatch. Further supporting the concept of the left hemidiaphragm as more potentially upwardly mobile and therefore more accommodating of a post-resection pleural space than the right, in studies examining series of symptomatic unilateral diaphragm paralysis, left *vs.* right side paralysis has been consistently over-represented (16-18).

Several limitations of the study should be highlighted. First, ICD-10 coding is at best not intuitive for clinicians and at worst frankly medically erroneous; a glaring example is the inclusion of lingulectomy in ICD-10 lobectomy codes. We included lingulectomy in our analysis here to remain consistent with ICD-10 convention but the lingula is not an anatomic pulmonary lobe and outside of ICD-10 lingulectomy is universally categorized as a segmentectomy operation. Segmentectomy and lung wedge are recognized as "excision" operations in ICD-10-PCS and lobectomy is designated as "resection" (6), so there is some internal ambiguity in ICD-10 terminology. In CPT coding, segmentectomy and lobectomy are referred to as "removal" and lung wedge is a "resection" leading to the potential for misunderstanding between users of ICD-10 and CPT. Furthermore, the term, "percutaneous endoscopic approach" (PEA), referring to a thoracoscopic or robotic approach to lobectomy is not used by surgeons and represents a step backwards from International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) which retained the terminology, "thoracoscopic lobectomy of lung" in code 32.41. While the potential for generalization or adaptability of the term, PEA, to procedures involving other body systems or organs is admitted, there is again potential for misunderstanding between surgeons and hospital coders due to a lack of uniform terminology which might ultimately lead to compromised patient care or in a less dire scenario to hospital billing errors due to miscoding. Importantly, before researchers launch into a time-consuming study involving ICD-10 it is critical for them to be clear about the mapping of the code(s) being searched. We have learned from discussion with the coders in our hospital that when they identify thoracoscopy in association with lobectomy in the medical record, whether in the wording of operative notes or CPT codes, they map this to PEA lobectomy in ICD-10-PCS. Miscoding of procedures by individuals or institutions remains a possibility (6) and as new and more complex coding systems will inevitably continue to appear, mapping between these coding systems may become increasingly convoluted (19).

Another important limitation to this study was that administrative databases like the TPUDF are primarily designed to track the activity of healthcare systems from a financial and administrative standpoint and not to facilitate clinical research (11). In the TPUDF lung cancer staging, pre-operative lung function testing, and detailed clinical information about post-operative complications specific to lobectomy are not tracked and mortality is only recorded as "expired" status at discharge not 30-day mortality. Therefore, accepted, risk-adjusted lobectomy quality metrics as reported in the GTSD (1) are not obtainable from TPUDF data and clinical forces underlying any observations of statistical differences between sub-populations in this analysis must be viewed as purely speculative. Lobectomy LOS and thoracoscopy adoption rate are not considered quality metrics in the GTSD (1). The TPUDF does represent the most complete, aggregate lobectomy data in our state as GTSD penetration remains low (20) with only 14 programs in the state of Texas reporting to the GTSD (21).

Additional anatomic lobe-specific findings surfaced in this study. More upper *vs.* lower lobe resections were performed for both right and left lungs which was likely attributable to primary lung cancer constituting the operative indication for lobectomy as 80% of cases also carried a lung cancer diagnosis. In the STS database 85% of lung lobectomy is for treatment of primary lung cancer (22) and the predominant histologic subtype, adenocarcinoma, presents disproportionately in upper *vs.* lower lung fields (23).

Finally, a greater rate of discharge to a SNF or some equivalent discharge status was seen in conjunction with open upper *vs.* lower lobe resection, though this finding did not extend to PEA resection. In general, it appeared that the differences in upper *vs.* lower lobe prolonged LOS or increased utilization of procedural or post-discharge resources were heightened by open *vs.* PEA approach to lobectomy.

Conclusions

While upper *vs.* lower lobe resection was more prevalent in a large pulmonary lobectomy population, consistent with lung adenocarcinoma upper lobe predominance, minimally invasive surgery was less commonly performed for upper than for right lower lobectomy. LOS, irrespective of surgical approach, was longer for upper *vs.* lower lobe resection as was need for transfer to additional inpatient facilities. LOS was longer and need for additional surgical or procedural interventions days after the primary procedure of lobectomy was greater for right *vs.* left upper lobe resection, suggesting some differential properties of the right *vs.* left pleural space. The marked clinical differences between anatomic lobes in the setting of pulmonary lobectomy observed in this study have the potential to translate to marked differences in expected hospital and health system costs and surgeon time-expenditure and experience premium that currently have no mechanism for their accounting. These findings highlight the value of ICD-10 coding for analysis of pulmonary lobectomy in administrative databases and suggest a possible path to more informed patient counseling and even potentially more equitable hospital and surgeon reimbursement based on payment adjustment by anatomic lobe in pulmonary lobectomy operations.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

References

1. Kozower BD, O'Brien SM, Kosinski AS, et al. The Society of Thoracic Surgeons Composite Score for Rating Program Performance for Lobectomy for Lung Cancer. Ann Thorac Surg 2016;101:1379-86; discussion 1386-7.
2. Brunelli A, Monteverde M, Borri A, et al. Predictors of prolonged air leak after pulmonary lobectomy. Ann Thorac Surg 2004;77:1205-10; discussion 1210.
3. Ferguson MK, Bennett C. Identification of Essential Components of Thoracoscopic Lobectomy and Targets for Simulation. Ann Thorac Surg 2017;103:1322-9.
4. Bryan DS, Ferguson MK, Antonoff MB, et al. Consensus for Thoracoscopic Left Upper Lobectomy-Essential Components and Targets for Simulation. Ann Thorac Surg 2021;112:436-42.
5. Sawada S, Komori E, Yamashita M. Evaluation of video-assisted thoracoscopic surgery lobectomy requiring emergency conversion to thoracotomy. Eur J Cardiothorac Surg 2009;36:487-90.
6. Clark JM, Utter GH, Nuño M, et al. ICD-10-CM/PCS: potential methodologic strengths and challenges for thoracic surgery researchers and reviewers. J Thorac Dis 2019;11:S585-95.
7. Available online: https://www.dshs.texas.gov/thcic/hospitals/Inpatientpudf.shtm
8. Yamada Y, Yamada M, Chubachi S, et al. Comparison of inspiratory and expiratory lung and lobe volumes among supine, standing, and sitting positions using conventional and upright CT. Sci Rep 2020;10:16203.
9. Petersen RH, Hansen HJ. Learning curve associated with VATS lobectomy. Ann Cardiothorac Surg 2012;1:47-50.
10. Yan TD, Cao C, D'Amico TA, et al. Video-assisted thoracoscopic surgery lobectomy at 20 years: a consensus statement. Eur J Cardiothorac Surg 2014;45:633-9.
11. Gavrielov-Yusim N, Friger M. Use of administrative medical databases in population-based research. J Epidemiol Community Health 2014;68:283-7.
12. McKenna RJ Jr. Complications and learning curves for video-assisted thoracic surgery lobectomy. Thorac Surg Clin 2008;18:275-80.
13. Urschel HC Jr, Razzuk MA. Median sternotomy as a standard approach for pulmonary resection. Ann Thorac Surg 1986;41:130-4.
14. Brasel KJ, Lim HJ, Nirula R, et al. Length of stay: an appropriate quality measure? Arch Surg 2007;142:461-5; discussion 465-6.
15. Silver AW, Espinas EE, Byron FX. The fate of the postresection space. Ann Thorac Surg 1966;2:311-36.
16. Laroche CM, Mier AK, Moxham J, et al. Diaphragm strength in patients with recent hemidiaphragm paralysis. Thorax 1988;43:170-4.
17. Elefteriades J, Singh M, Tang P, et al. Unilateral diaphragm paralysis: etiology, impact, and natural history. J Cardiovasc Surg (Torino) 2008;49:289-95.
18. Caleffi-Pereira M, Pletsch-Assunção R, Cardenas LZ, et al. Unilateral diaphragm paralysis: a dysfunction restricted not just to one hemidiaphragm. BMC Pulm Med 2018;18:126.
19. Niyirora J. Entropic measures of complexity in a new medical coding system. BMC Med Inform Decis Mak 2021;21:124.
20. Tong BC, Kim S, Kosinski A, et al. Penetration, Completeness, and Representativeness of The Society of Thoracic Surgeons General Thoracic Surgery Database for Lobectomy. Ann Thorac Surg 2019;107:897-902.
21. Available online: https://www.sts.org/sites/default/files/content/DBParticipantMap_2019.png
22. Seder CW, Salati M, Kozower BD, et al. Variation in Pulmonary Resection Practices Between The Society of Thoracic Surgeons and the European Society of Thoracic Surgeons General Thoracic Surgery Databases. Ann Thorac Surg 2016;101:2077-84.
23. Kinsey CM, Estepar RS, Zhao Y, et al. Invasive adenocarcinoma of the lung is associated with the upper lung regions. Lung Cancer 2014;84:145-50.

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