National Analysis of Unplanned Readmissions After Thoracoscopic Versus Open Lung Cancer Resection

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Background. **Hospital readmissions are viewed as a mark of inferior health care quality and are penalized. Unplanned postoperative readmission reason and timing after lung resection are not well understood. We examine related, unplanned readmissions after thoracoscopic versus open anatomic lung resections to identify opportunities to improve patient care.**

Methods. **We analyzed the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) data set, 2012 to 2015, characterizing 30-day related, unplanned postoperative readmissions after anatomic lung resections for primary lung cancer. Risk-adjusted comparison of readmission after thoracoscopic and open resection was performed using propensity matching.**

Results. **Patients (n = 9,510) underwent anatomic lung resections; 4,935 (51.9%) were thoracoscopic resections and 4,575 (48.1%) were open resections. Of the thoracoscopic patients, 10.9% experienced one or more complications, versus 19.4% of patients with open resection ($p < 0.0001$). Of the thoracoscopic patients 5.5% experienced related, unplanned readmissions versus 7.2% of the patients with open resection ($p < 0.001$). 24.8% of complications after thoracoscopic approach occurred after discharge, versus 15.5% after open approach ($p < 0.0001$). Timing of unplanned readmission was similar for both groups. The propensity-matched odds ratio of risk of readmission after thoracoscopic versus open resection was 1.16 (95% confidence interval, 0.949 to 1.411, $p = 0.15$).**

Conclusions. **Open anatomic lung resections for primary lung cancer had nearly twice the complication rate but only a slightly higher readmission rate than thoracoscopic resection. More complications occurred after discharge after thoracoscopic than open resections. Most readmissions occurred within 2 weeks after both thoracoscopic and open resections. Risk-adjusted comparison identified no statistically significant difference in risk of related, unplanned readmission after thoracoscopic versus open resections. Future studies should focus on identification of processes of care to decrease complications and unplanned readmissions after lung cancer resection.**

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Readmission after thoracic operation ranges between 11% and 24% and is associated with postoperative complications [1, 2]. High readmission rates are associated with inferior health care, a problem recognized by health care providers, policy makers, and patients, and are penalized under the Affordable Care Act [3–5].

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Abbreviations and Acronyms

ACS NSQIP PUF	=	American College of Surgeons National Surgical Quality Improvement Program Participant Use File
CI	=	confidence interval
CPT	=	Current Procedural Terminology
ICD-9-CM	=	International Classification of Diseases Ninth Revision Clinical Modification
LOS	=	length of stay
OR	=	odds ratio
SSI	=	surgical site infection
UTI	=	urinary tract infection
VTE	=	venous thromboembolism

Both open and minimally invasive lung resection operations for primary lung cancer are commonly performed. Video-assisted thoracoscopic surgery typically results in shorter hospital stays and is associated with fewer postoperative complications [6]. Whether complications after discharge are related to increased readmissions is especially poignant because attention has turned to shortened length of stay (LOS) [7, 8].

Identifying patients at the greatest risk of postoperative complications that result in readmission could direct resources to reduce this. To understand this, we examined related, unplanned readmission after thoracoscopic versus open resection for lung cancer. Factors examined include operation type, postoperative complications, LOS, and timing of readmission after operation.

Patients and Methods

We identified patients aged 18 years and older who underwent anatomic lung resections for primary lung cancer in the American College of Surgeons National Surgical Quality Improvement Program Participant Use File (ACS NSQIP PUF), 2012 to 2015. The ACS NSQIP PUF collects preoperative patient variables, operative data, and 30-day postoperative outcomes for a sample of patients undergoing operation, including patient demographic characteristics, preoperative comorbidities, operative data, 30-day postoperative complications, and LOS. Patients undergoing anatomic lung resection were identified using Current Procedural Terminology (CPT) codes and International Classification of Disease (ICD) codes, and subsequently were divided into thoracoscopic and open groups according to operation type. Patients were excluded if they died during index admission. The indications for operation are provided in Supplemental Table 1.

Related, unplanned readmission was defined by the ACS NSQIP PUF as readmission related to the index operation, occurring within 30 days of operation without documented plans for readmission. Related, unplanned readmission reasons were classified into groups using the ACS NSQIP-reported postoperative complications and ICD Ninth Revision Clinical Modification (9-CM) or ICD Tenth Revision Clinical Modification (10-CM) diagnosis code, followed by free text. The 18 reported ACS NSQIP perioperative complications were grouped into the following eight categories based on our prior research: (1) pulmonary (prolonged intubation >48 hours, unplanned intubation, pneumonia, and septic shock), (2) infectious (sepsis, deep incisional surgical site infection [SSI], organ/space SSI, superficial SSI, and wound disruption), (3) urinary tract infection (UTI), (4) cardiac (myocardial infarction, cardiac arrest that required cardiopulmonary resuscitation), (5) transfusion (bleeding that required packed red cell transfusion), (6) renal (acute renal failure that required dialysis or hemofiltration, and progressive renal insufficiency), (7) venous thromboembolism (VTE) (deep venous thrombosis/thrombophlebitis that required treatment, and pulmonary embolism), and (8) neurologic (stroke/cerebrovascular accident with neurologic deficit) [9]. Additional complication categories were (9) gastrointestinal, (10) pain, (11) metabolic, (12) malignancy, (13) other, and (14) unknown. Pleural effusion, pneumothorax, subcutaneous emphysema, postoperative air leak, dyspnea, and respiratory failure were also characterized as pulmonary complicaitons (Supplemental Table 2). Fisher exact test was used for categorical variables. The *t* test or Wilcoxon rank-sum test was used for continuous variables. The association between readmission reason and CPT grouping was tested with χ^2. Time between discharge and related, unplanned readmission was described using histograms.

Propensity matching was used to compare related, unplanned readmissions after thoracoscopic versus open resection. A propensity score for each patient was calculated using a multivariable logistic regression model in which the dependent variable was treatment group (thoracoscopic and open resection) and the independent variables were those that occurred before discharge, including patient preoperative and operative factors, LOS, discharge destination, wound class, and occurrence of in-hospital complications. For the propensity model the β-coefficients were combined with the patient's values for each covariate to generate model-specific propensity scores for each patient. Patient-level propensity scores were used to match thoracoscopic patients 1:1 to open patients to produce the propensity-matched cohort using the greedy matching method. The quality of the matching process was assessed by comparing the standardized differences between treatment groups for the covariates before and after matching [10]. Absolute standardized differences 0.1 or less indicate groups are well balanced for that characteristic. Generalized estimating equation models were used to test our hypothesis of no difference in risk-adjusted readmission rates between thoracoscopic and open resections for the propensity-matched cohort to account for correlation within each matched pair. As a sensitivity analysis, we performed multivariable logistic regression analysis on the full cohort of patients to test our hypotheses about the association between thoracoscopic and open anatomic lung resections and related, unplanned readmission.

Significance was set at a two-sided p value less than 0.05 for propensity analysis and multivariable logistic regression analysis.

Comparison of LOS after index lung resection, frequency of occurrence, and identification of complications after discharge (postdischarge morbidity) and related, unplanned readmission between the two cohorts was also performed. SAS software version 9.4 (SAS Inc, Cary, NC) was used for analyses. Our institutional review board determined this study exempt from review.

Results

Anatomic lung resection was identified in 9,758 patients in the ACS NSQIP PUF, 2012 to 2015. One hundred twenty-five patients (1.3%) died in the hospital, and 9,633 patients (98.7%) were discharged alive from the hospital. One hundred twenty-three patients (1.3%) patients were excluded because of missing key data (readmission status, complication timing, comorbidities), resulting in an analytic cohort of 9,510 patients (97.5%). Of these 4,935 patients (51.9%) underwent thoracoscopic anatomic lung resection (4,348 lobectomies, 552 segmentectomies, 35 pneumonectomies) and 4,575 patients (48.1%) underwent open anatomic lung resection (3,618 lobectomies, 386 pneumonectomies, 296 bilobectomies, 275 segmentectomies) (Table 1).

Demographic and preoperative characteristics of the patient cohort compared by thoracoscopic versus open resection are reported in Supplemental Table 3. In general, the patients who underwent thoracoscopic resection were more frequently women, slightly older, but also slightly healthier than patients who underwent open anatomic lung resection. The total complication rate after thoracoscopic resection was 540 (10.9%) compared with 886 (19.4%) after open resection ($p < 0.0001$). Pulmonary, transfusion, and infectious complications were the most prevalent, occurring in 289 (5.9%), 165 (3.3%), and 106 (2.2%) of thoracoscopic patients, respectively, and 430 (9.4%), 412 (9.0%), and 130 (2.8%) of open anatomic lung resection patients, respectively.

Of the total cohort of patients, 603 (6.3%) experienced a related, unplanned readmission. Of the 4,935 thoracoscopic patients, 273 (5.5%) experienced a related, unplanned readmission, compared with 330 (7.2%) of 4,575 open resection patients ($p < 0.001$) (Supplemental Table 3). ICD-9-CM provided readmission reasons for 400 patients (66.3%), ICD-10-CM for 2 patients (0.3%), and recorded reasons for 201 patients (33.3%) (Supplemental Table 2).

Table 1. Sample Size by Anatomic Lung Resection Type ($n = 9,510$)

CPT Code	Description	No.	%
Thoracoscopic (total)		4,935	51.9
32663	Thoracoscopic lobectomy	4,348	45.7
32669	Thoracoscopic segmentectomy	552	5.8
32671	Thoracoscopic pneumonectomy	32	0.4
Open (total)		4,575	48.1
32480	Lobectomy	3,618	38.0
32440	Pneumonectomy	386	4.1
32482	Bilobectomy	296	3.1
32484	Segmentectomy	275	2.9

CPT = Current Procedural Terminology.

Of the 4,935 thoracoscopic patients, 540 (10.9%) experienced one or more postoperative complication. Of these 540 complications, 390 (72.2%) were identified during index admission, 131 (24.3%) after discharge, and 19 (3.5%) both during and after index admission. Of the 111 thoracoscopic patients who experienced a complication and were readmitted, complications were identified in 18 (16.2%) during index admission, in 84 (75.7%) after discharge, and in 9 (8.1%) both during and after index admission. Of the 4,575 open resection patients, 886 (19.4%) had one or more postoperative complications. Of these 886 complications, 696 (78.6%) were identified during index admission, 138 (15.6%) after discharge, and 52 (5.9%) both during and after index admission. Of the 164 open resection patients who experienced a complication and were readmitted, complications were identified in 32 (19.5%) during index admission, in 105 (64.0%) after discharge, and in 27 (16.5%) both during and after index admission (Table 2).

When reason for related, unplanned readmission was known, pulmonary complications accounted for 152 (55.7%) of thoracoscopic versus 171 (51.8%) of open patient readmissions. Pneumothorax was the single most common cause of unplanned readmission after thoracoscopic resection (59, 21.6%), occurring more than after open resection (47, 14.2%). Pneumonia, the leading cause of readmission after open resection (65, 19.7%), only occurred in 44 (16.1%) thoracoscopic patients who required readmission. Infectious complications (excluding pneumonia) were more commonly associated with readmission after open resection (59, 17.9%) than after thoracoscopic resection (30, 11.0%). VTE was more commonly associated with unplanned readmission after open resection (19, 5.8%) than after thoracoscopic resection (14, 5.1%). Cardiac complications were more commonly associated with readmission after thoracoscopic resection (14, 5.1%) than after open resection (14, 4.2%). Pain was associated with unplanned readmission more frequently after open resection (15, 4.5%) than after thoracoscopic resection (7, 2.6%). Gastrointestinal complications were more commonly associated with readmission after thoracoscopic resection (10, 3.7%) than after open resection (11, 3.3%). A summary of these findings are presented in Table 3. Multiple other complications associated with related, unplanned readmission occurred with a low frequency after both thoracoscopic and open resections, including metabolic, transfusion, neurologic, UTI, renal failure, malignancy, and other reasons (Supplemental Table 4).

Postoperative complications were compared with reasons for readmission for 409 patients in whom these data were available (Table 4). For patients in both the open and thoracoscopic resection groups, greater than 50% concordance was demonstrated for postoperative

Table 2. Rate and Timing of Complications After Anatomic Lung Resection, Including In-Patients Who Experienced Related, Unplanned Readmission

	Complication After Open Resection (n = 886)		Complication After Thoracoscopic Resection (n = 540)	
Complications	All Patients	Readmitted Patients	All Patients	Readmitted Patients
One or more complications	886	164	540	111
Occurrence of one or more in-hospital complications	696 (78.6)	32 (19.5)	390 (72.2)	18 (16.2)
Occurrence of one or more postdischarge complications	138 (15.6)	105 (64.0)	131 (24.3)	84 (75.7)
Occurrence of one or more in-hospital and postdischarge complications	52 (5.9)	27 (16.5)	19 (3.5)	9 (8.1)

Values are n or n (%).

neurologic, pulmonary, VTE, and infectious complications, and less than 50% concordance for all other complications.

Within 7 days of discharge, 156 of 268 unplanned readmissions (58%) occurred in the thoracoscopic resection group versus 176 of 327 (54%) in the open resection group (Fig 1). Within 14 days of discharge, 216 unplanned readmissions (81%) occurred in the thoracoscopic resection group versus 266 (82%) in the open resection group. Although most readmissions for pulmonary reasons occurred within the first 2 weeks after both thoracoscopic and open resections (Supplemental Fig 1A), readmissions for infectious reasons occurred less predictably (Supplemental Fig 1B).

Comparison of the likelihood of experiencing a related, unplanned readmission between the unmatched sample of 4,935 thoracoscopic resection patients and 4,575 open resection patients demonstrated an odds ratio (OR) of 0.753 (95% confidence interval [CI]): 0.638 to 0.889, $p < 0.001$) (Table 5). The propensity analysis matched 3,399 thoracoscopic to 3,399 open resection patients. On propensity matching, we found no significant difference in the risk of related, unplanned readmission after thoracoscopic versus open resection (OR 0.847, 95% CI: 0.696 to 1.030, $p = 0.10$) (Table 5). Patient and postoperative characteristics before and after matching for open and thoracoscopic resections are presented in Supplemental Table 5, including the 19 preoperative independent variables that were included in the propensity analysis (age, sex, place of origin of admission, diabetes mellitus, current smoker status, dyspnea, functional health status before operation, severe chronic obstructive pulmonary disease, disseminated cancer, >10% loss of body weight, bleeding disorder that required hospitalization, transfusion of packed red blood cells, inpatient/outpatient operation, primary surgeon specialty, American Society of Anesthesiology physical status classification, LOS, surgical wound class, discharge destination, and in-hospital complication). Before matching, 7 of 19 variables had absolute standardized differences greater than 0.1; after matching all 19 variables had absolute standardized differences of 0.1 or less. Despite applying a range of calipers there was no statistically significant difference in readmissions between thoracoscopic versus open resection patients.

The multivariable logistic regression performed for sensitivity analysis concurred with the propensity matching (OR 0.948, 95% CI: 0.741 to 1.212, $p = 0.67$)

Table 3. Summary of Related, Unplanned Readmission Reasons After Anatomic Lung Resection[a]

Complication Category	Total (n = 603)	Open (n = 330)	Thoracoscopic (n = 273)	*p* Value
Pulmonary	323 (53.6)	171 (51.8)	152 (55.7)	0.29
Pneumonia	109 (18.1)	65 (19.7)	44 (16.1)	
Pneumothorax	106 (17.6)	47 (14.2)	59 (21.6)	
Pleural effusion	46 (7.6)	24 (7.3)	22 (8.1)	
Infection	89 (14.8)	59 (17.9)	30 (11)	0.002
Organ/space SSI	40 (6.6)	24 (7.3)	16 (5.9)	0.15
Venous thromboembolic	33 (5.5)	19 (5.8)	14 (5.1)	0.38
Cardiac	28 (4.6)	14 (4.2)	14 (5.1)	1.00
Gastrointestinal	21 (3.5)	11 (3.3)	10 (3.7)	0.83
Pain	22 (3.6)	15 (4.5)	7 (2.6)	0.09

[a] Full data can be found in Supplemental Table 4.

Values are n (%).

SSI = surgical site infection.

Table 4. Agreement Between Related, Unplanned Readmission Reasons and Postoperative Complications After Anatomic Lung Resection

Postoperative Complication	Readmission Reasons After						
	Open Resection		Thoracoscopic Resection		Any Type of Resection		
	Same	Different	Same	Different	Same	Different	Total
Pulmonary	68 (70.1)[a]	29 (29.9)	48 (72.7)[a]	18 (27.3)	116 (71.2)[a]	47 (28.8)	163
Infection	35 (59.3)[a]	24 (40.7)	23 (60.5)[a]	15 (39.5)	58 (59.8)[a]	39 (40.2)	97
Transfusion	0 (0.0)	37 (100)	0 (0.0)	13 (100)	0 (0.0)	50 (100)	50
VTE	16 (59.3)[a]	11 (40.7)	12 (63.2)[a]	7 (36.8)	28 (60.9)[a]	18 (39.1)	46
UTI	1 (10.0)	9 (90.0)	2 (40.0)	3 (60.0)	3 (20.0)	12 (80.0)	15
Cardiac	1 (10.0)	9 (90.0)	1 (20.0)	4 (80.0)	2 (13.3)	13 (86.7)	15
Renal	2 (25.0)	6 (75.0)	2 (40.0)	3 (60.0)	4 (30.8)	9 (69.2)	13
Neurologic	4 (80.0)[a]	1 (20.0)	4 (80.0)[a]	1 (20.0)	8 (80.0)[a]	2 (20.0)	10

[a] Concordance greater than 50%.

Values are n or n (%).

UTI = urinary tract infection; VTE = venous thromboembolism.

(Table 5). An indicator variable was included for extent of resection (segmentectomy, lobectomy/bilobectomy, or pneumonectomy). Regardless of thoracoscopic or open approach, patients who underwent pneumonectomy were more likely to be readmitted than patients who underwent segmentectomy but not lobectomy or bilobectomy ($p = 0.05$). This suggests that there is a small difference in related, unplanned readmissions between operation types even after controlling for approach.

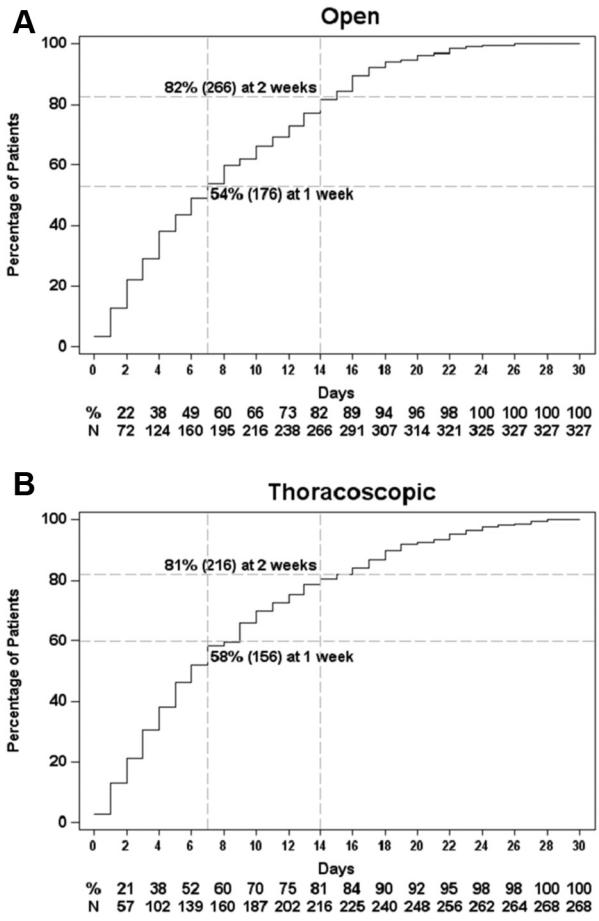

Fig 1. Time to related, unplanned readmission from discharge after (A) open and (B) thoracoscopic anatomic lung resections.

We evaluated if the LOS after the index lung resection was correlated with postdischarge morbidity and with unplanned readmissions. Shorter LOS was associated with both increased frequency of postdischarge morbidity (Fig 2A) and related, unplanned readmission (Fig 2B) after both thoracoscopic and open anatomic lung resection for lung cancer.

Comment

Limited data exist on readmissions after anatomic lung resection. Prior review of the ACS NSQIP database revealed an overall 30-day readmission rate for thoracic operations of 11.1% [11]. Although prior studies have outlined postoperative characteristics, including readmission, after open and thoracoscopic resections, they have not examined related, unplanned readmissions specifically [12]. Our study represents the largest multiple institutional analysis of related, unplanned readmissions after thoracoscopic versus open anatomic lung resection

Table 5. Comparison of Related, Unplanned Readmission Between Thoracoscopic and Open Anatomic Lung Resection

Analysis	OR (95% CI) of Readmission	*p* Value
Unadjusted[a]	0.753 (0.638–0.889)	<0.001
Propensity matched[b]	0.847 (0.696–1.030)	0.10
Multivariable adjusted[a]	0.948 (0.741–1.212)	0.67

[a] Unmatched sample size: VATS = 4,935, Open = 4,575. [b] Matched sample size: VATS = 3,399, Open = 3,399.

CI = confidence interval; OR = odds ratio; VATS = video-assisted thoracoscopic surgery.

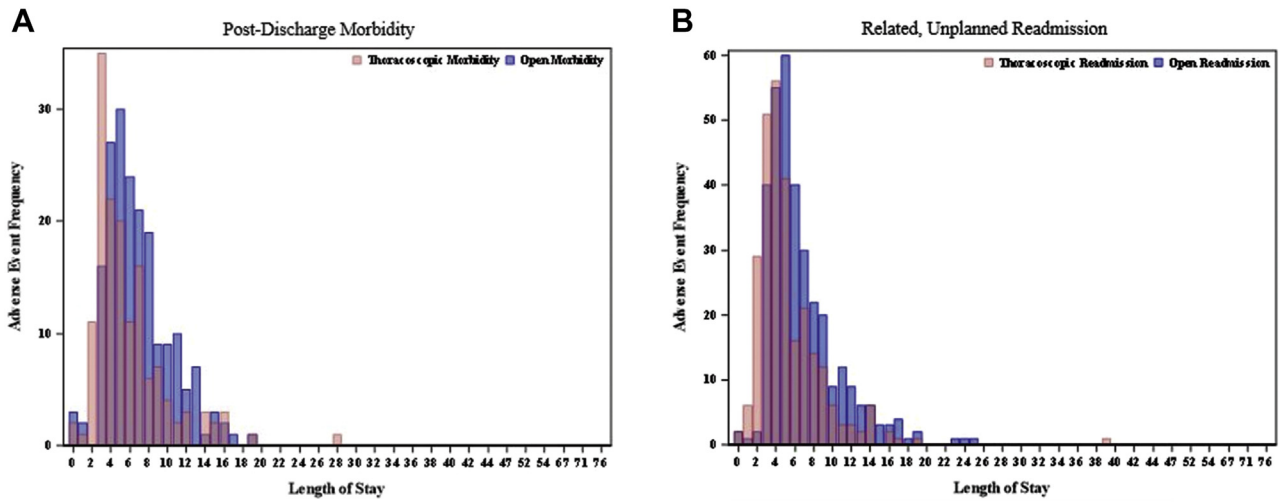

Fig 2. The frequency of (A) postdischarge morbidity and (B) related, unplanned readmission by length of stay.

for primary lung cancer. After propensity-matching risk adjustment, we found no statistically significant difference in odds of related, unplanned readmission between the two surgical approaches. We also report notable findings about complications and readmission after lung cancer resection.

Complications occur almost twice as frequently after open versus thoracoscopic resection with more complications occurring after discharge after thoracoscopic than open resection, consistent with prior studies [13]. A lower proportion of patients with complications after open resection than thoracoscopic resection required readmission. This suggests that more complications are identified and managed during the longer LOS associated with open anatomic lung resection, leading to fewer complications that present after discharge and require readmission for management.

Most complications occurred as an inpatient for all patients undergoing resection for lung cancer. However, in the subset of patients who experienced readmission most complications occurred after discharge. Related, unplanned readmission occurred considerably more frequently after open resection than after thoracoscopic resection. Pneumothorax was the leading cause of unplanned readmission after thoracoscopic resection, and pneumonia was the leading cause of readmission after open resection, similar to findings of Freeman and colleagues [5]. Postoperative, postdischarge complications, specifically pulmonary and infectious complications, drive unplanned readmissions after anatomic lung resection, in agreement with earlier studies [14]. Occurrence of VTE, pulmonary, infectious, and neurologic complications after operation correlated with unplanned readmission for the same reason. Thus, occurrence of these complications are predictors of unplanned readmission for these same complications and should raise awareness in practitioners.

We found that shorter LOS is associated with both increased frequency of postdischarge complications and related, unplanned readmission. After both thoracoscopic and open resections, most patients who experienced an unplanned readmission did so within the first week of discharge. Median LOS after thoracoscopic resection was substantially shorter than LOS after open resection, and a greater percentage of patients readmitted after thoracoscopic resection than open resection were done so during the first week. We conclude that shorter LOS, particularly after thoracoscopic resection, drives increased readmissions sooner after operation.

Patients who underwent thoracoscopic resection had a lower overall complication rate, shorter LOS, lower rate of unplanned reoperation, and were more likely to be discharged home, versus patients undergoing open resection. These differences in postoperative outcomes between open and thoracoscopic resections are likely a surrogate for differences in the patients who are selected for thoracoscopic versus open resection as identified in prior studies using different data sources [12]. After risk adjustment, there was no difference in the risk of unplanned readmission after thoracoscopic versus open resection, consistent with the findings of Assi and colleagues [15].

Historically, readmission rates have been determined using administrative data [16]. The ACS NSQIP-collected data on postoperative readmissions have been demonstrated to be superior to claims data for such analysis because its accuracy in identifying all-cause and unplanned readmissions has been validated [17]. Readmissions to any hospital, not just the index hospital, are captured by the ACS NSQIP, therefore improving its accuracy at capturing all readmissions over claims data [18]. In addition, the ACS NSQIP PUF records information on readmission reason, distinguishing between planned and unplanned, and related and unrelated readmissions [19]. Prior analyses have shown that readmission after lung cancer resection is associated with a significantly increased short-term mortality rate [20]. Although readmissions are associated with postoperative morbidity, quality of care is likely not the cause of readmission. Nonmodifiable comorbidities are frequently associated with postoperative readmission [15]. Kansagara and colleagues [21] and Joynt

and colleagues [22] showed relationships between discharge process and discharge resources as a cause of readmission rather than quality of care [2]. Readmissions are also costlier than prolonged length of index hospitalization, related to admission costs, emergency department costs, and complication severity [5].

Unlike the Centers for Medicare and Medicaid Services definition of readmission (within 30 days of discharge) the ACS NSQIP tracks readmissions and complications for only 30 days after the index operation. Therefore, complications and readmissions occurring more than 30 days after the index operation are not reported. Some variables that may factor into operative approach and unplanned readmission are not recorded in the ACS NSQIP PUF, including preoperative pulmonary function, cancer stage, administration of preoperative chemo/radiotherapy, and geographic and socioeconomic factors. These unrecorded factors may contribute to the difference between the open and thoracoscopic populations. Characterization of patients undergoing planned versus unplanned and related versus unrelated readmissions, as reported by ACS NSQIP reviewers, was taken at face value, without ability to verify these. Data on readmission reason in the ACS NSQIP PUF are not as straightforward as that on postoperative complications. Patients may be readmitted for multiple reasons, but only one is recorded. Our clustering of readmission reasons demonstrates that reasons stated in charts vary widely. Developing a standardized list of readmission reasons comparable with our data-driven clustering of postoperative complications may ease future tracking, analysis, and intervention on readmissions [9]. Date of follow-up appointments is not available, preventing further confirmation of our suspicion that most readmissions occur before them. Although using The Society of Thoracic Surgeons General Thoracic Database would overcome some of these limitations, it would reflect the outcomes of predominantly thoracic surgeons, not that of the mix of general, cardiothoracic, and thoracic surgeons who perform lung operations in the United States, as better reflected in the ACS NSQIP PUF.

Numerous efforts to reduce postoperative complications exist [23]. However, intervention relies on accurate and early identification of complications. Given that a quarter of complications become clinically apparent after discharge, and these are correlated with unplanned readmissions, efforts to identify complications that occur as an outpatient will provide an opportunity for intervention. Because most complications leading to readmission are pulmonary and infectious in nature and occur within the first 2 weeks of discharge, the typical follow-up of a clinic appointment 2 weeks after discharge may not be adequate to capture these issues. Instead, surveillance methods to detect and manage postdischarge complications in conjunction with earlier outpatient follow-up may serve to prevent unplanned readmissions [15, 24–27]. Further, improved patient and family education about signs and symptoms and how to manage common postoperative issues could decrease the rate of unplanned readmissions after lung resection. Further analysis of readmission after lung cancer should focus on identifying which types of complications are associated with readmission after risk adjustment of thoracoscopic versus open resections and how these can be prevented or treated to minimize related, unplanned readmissions.

In conclusion, we found that thoracoscopic anatomic lung resection for lung cancer is associated with a higher rate of postdischarge complications than open anatomic lung resection, but overall open resection had an increased rate of related, unplanned readmissions. On risk adjustment, there was no notable difference in the odds of related, unplanned readmission between thoracoscopic and open resections. Earlier discharge after thoracoscopic versus open resection is associated with increased related, unplanned readmissions. Most patients are readmitted within the first week of discharge. Prior studies have demonstrated improved identification of postdischarge complications. Additional efforts should be focused at reduction of and early identification of postdischarge surgical complications to reduce readmissions.

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References

1. Weiss AJ, Elixhauser A, Steiner C. Readmissions to U.S. Hospitals by Procedure, 2010: Statistical Brief #154. Rockville, MD: Agency for Healthcare Research and Quality; 2006.
2. Lawson EH, Hall BL, Louie R, et al. Association between occurrence of a postoperative complication and readmission: implications for quality improvement and cost savings. Ann Surg 2013;258:10–8.
3. Rosen AK, Loveland S, Shin M, et al. Examining the impact of the AHRQ Patient Safety Indicators (PSIs) on the Veterans Health Administration: the case of readmissions. Med Care 2013;51:37–44.
4. Polanczyk CA, Newton C, Dec GW, Di Salvo TG. Quality of care and hospital readmission in congestive heart failure: an explicit review process. J Card Fail 2001;7:289–98.
5. Freeman RK, Dilts JR, Ascioti AJ, Dake M, Mahidhara RS. A comparison of length of stay, readmission rate, and facility reimbursement after lobectomy of the lung. Ann Thorac Surg 2013;96:1740–5.

6. Whitson BA, Groth SS, Duval SJ, Swanson SJ, Maddaus MA. Surgery for early-stage non-small cell lung cancer: a systematic review of the video-assisted thoracoscopic surgery versus thoracotomy approaches to lobectomy. Ann Thorac Surg 2008;86:2008–16.
7. Bowers J, Cheyne H. Reducing the length of postnatal hospital stay: implications for cost and quality of care. BMC Health Serv Res 2016;16:16.
8. Reed T, Jr, Veith FJ, Gargiulo NJ, III, et al. System to decrease length of stay for vascular surgery. J Vasc Surg 2004;39:395–9.
9. Meguid RA, Bronsert MR, Juarez-Colunga E, Hammermeister KE, Henderson WG. Surgical Risk Preoperative Assessment System (SURPAS): I. Parsimonious, clinically meaningful groups of postoperative complications by factor analysis. Ann Surg 2016;263:1042–8.
10. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. Stat Med 2009;28:3083–107.
11. Lucas DJ, Haider A, Haut E, et al. Assessing readmission after general, vascular, and thoracic surgery using ACS-NSQIP. Ann Surg 2013;258:430–9.
12. Stiles BM, Poon A, Giambrone GP, et al. Incidence and factors associated with hospital readmission after pulmonary lobectomy. Ann Thorac Surg 2016;101:434–42.
13. Desai H, Natt B, Kim S, Bime C. Decreased in-hospital mortality after lobectomy using video-assisted thoracoscopic surgery compared with open thoracotomy. Ann Am Thorac Soc 2017;14:262–6.
14. Rajaram R, Ju MH, Bilimoria KY, Ko CY, DeCamp MM. National evaluation of hospital readmission after pulmonary resection. J Thorac Cardiovasc Surg 2015;150:1508–14.
15. Assi R, Wong DJ, Boffa DJ, et al. Hospital readmission after pulmonary lobectomy is not affected by surgical approach. Ann Thorac Surg 2015;99:393–8.
16. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med 2009;360:1418–28.
17. Sellers MM, Merkow RP, Halverson A, et al. Validation of new readmission data in the American College of Surgeons National Surgical Quality Improvement Program. J Am Coll Surg 2013;216:420–7.
18. Glebova NO, Hicks CW, Taylor R, et al. Readmissions after complex aneurysm repair are frequent, costly, and primarily at nonindex hospitals. J Vasc Surg 2014;60:1429–37.
19. Zhang JQ, Curran T, McCallum JC, et al. Risk factors for readmission after lower extremity bypass in the American College of Surgeons National Surgery Quality Improvement Program. J Vasc Surg 2014;59:1331–9.
20. Hu Y, McMurry TL, Isbell JM, Stukenborg GJ, Kozower BD. Readmission after lung cancer resection is associated with a 6-fold increase in 90-day postoperative mortality. J Thorac Cardiovasc Surg 2014;148:2261–7.
21. Kansagara D, Englander H, Salanitro A, et al. Risk prediction models for hospital readmission: a systematic review. JAMA 2011;306:1688–98.
22. Joynt KE, Orav EJ, Jha AK. Thirty-day readmission rates for Medicare beneficiaries by race and site of care. JAMA 2011;305:675–81.
23. Berrios-Torres SI, Umscheid CA, Bratzler DW, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. JAMA Surg 2017;152:784–91.
24. Hornick JR, Balderman JA, Eugea R, Sanchez LA, Zayed MA. A telephone call 1 week after hospitalization can identify risk factors for vascular surgery readmission. J Vasc Surg 2016;64:719–25.
25. Antonoff MB, Ragalie W, Correa AM, et al. Results of postdischarge nursing telephone assessments: persistent symptoms common among pulmonary resection patients. Ann Thorac Surg 2016;102:276–81.
26. Daneman N, Lu H, Redelmeier DA. Discharge after discharge: predicting surgical site infections after patients leave hospital. J Hosp Infect 2010;75:188–94.
27. Sands K, Vineyard G, Livingston J, Christiansen C, Platt R. Efficient identification of postdischarge surgical site infections: use of automated pharmacy dispensing information, administrative data, and medical record information. J Infect Dis 1999;179:434–41.

DISCUSSION

DR RICHARD K. FREEMAN (Indianapolis, IN): For those of you that do not know, our presenter is actually an undergraduate student. So I congratulate you on your presentation and your poise today.

You and your coauthors found that the rates of complications and readmissions were significantly higher in thoracotomy patients compared with VATS [video-assisted thoracoscopic surgery] patients, but a correlation between postoperative complications and readmissions could not be consistently demonstrated.

I have two questions for you. The first. As you mentioned, our group in 2013 did report a series of 4,300 lobectomies, all by thoracotomy, looking at 90-day readmissions rate. We found a strong correlation between length of stay and readmission rate, with a breakpoint at 5 days. In other words, patients discharged before the fifth postoperative day had a significantly higher rate of readmission than patients who stayed 5 or more days after operation. Did you find any similar correlation?

MR BHAGAT: We recently found that minimally invasive approaches had a shorter length of stay and a high rate of postdischarge complications resulting in readmissions. We did not perform an analysis like you suggested with length of stay, but we do note that in your analysis, prolonged length of stay is more cost efficient than a readmission.

DR FREEMAN: The second question is more philosophical, so there is no wrong answer. Recent investigations have suggested that readmission rate alone is not an optimal measure of quality but rather a measure of resource utilization or cost. Based on your work, do you think we should be measuring readmissions as a quality metric? If so, what interval should we be measuring, 30, 60, or 90 days?

MR BHAGAT: You pointed out that readmissions may be more indicative of cost and quality. There are many factors that could be associated with readmissions, but our group believes that postoperative complications might be a better way to characterize quality of health care.

As for a specific cut off, we might think that it is better to use a standardized definition for readmissions. Instead of, say, 30 days arbitrarily or 90 days arbitrarily, it should be standardized.

DR MARA ANTONOFF (Houston, TX): Did you stratify the patients at all by comorbidities, pulmonary function tests, use of blood thinners preoperatively, or anything else of that sort?

MR BHAGAT: We did not stratify them like that. We split them up into open and VATS. We did characterize the comorbidities of these patients, but we did not put them into specific groups based on that.

DR ANTONOFF: My other question has to do with your preparation of the patients for discharge. We recently looked at a group of patients in whom we performed pulmonary resection over a 12-month period, and we found that patients who had less invasive operations, robotic and thoracoscopic procedures, and also women were discharged after a shorter length of stay, and we found that those patients when telephoned by nurses from our thoracic center 3 to 4 days after operation frequently had problems and needs that were unmet at that point in time; about 30% of our patients had needs that were unmet. Many of them could be addressed in telephone counseling; many of them required readmission or escalation to a higher level of care. And that led us to believe that the ways that we were preparing our patients for discharge really needed to be modified either through increased preoperative teaching in a clinic setting or better teaching in a perioperative setting during inpatient admission.

Can you tell us a little bit about how your patients prepared for discharge and what types of preoperative teaching you used to try to minimize these types of complications and readmissions that may occur in a postdischarge setting?

MR BHAGAT: As Dr Freeman noted, I am a student. The senior investigator, Dr Meguid, could expand on that. But what we were talking about is keeping patients in the hospital or area long enough to deal with those problems. Is it more cost effective, as Dr Freeman's study has shown, than readmitting patients later on.

DR MEGUID: Dr Antonoff, the study sample is from NSQIP, so we do not have any of that preoperative information, unfortunately. Our institution pools, as many institutions do, multiple states; we treat patients from about seven states at the University of Colorado. We found, along the lines of your study that you presented at the Western Thoracic Surgical Association 2 years ago, that if a patient lives more than about 4 hours away from the hospital, it is hard for us to get them back to see us should they have an urgent issue. So we may opt to treat those patients with a little bit more time in the hospital. That is not necessarily as cost effective as a discharge, but it is aimed at reducing unplanned readmissions.

DR DANIEL L. MILLER (Marietta, GA): We have instituted a 48-hour call, just like what you were talking about, I mean, the sooner the better, and it kind of nips a lot of things.

Now, were they readmitted back to your institution? Because a lot of times if they are farther away, they will go to an emergency department, they get a chest x-ray and it is a normal postoperative film, and they say, oh, you have pneumonia. There is no way we can prevent that. We have to do a better job as far as communication and so forth.

MR BHAGAT: Part of the reason that we want to keep people in the hospital or area a bit longer is because when we send them back several states away, there is a reason they came, because there are probably no thoracic surgeons there. So those surgeons and those providers may not be able to treat them in an outpatient setting. So if you can keep them there, I guess the idea would be that if you have a thoracic surgeon that did the operation at that site, then they could treat the patient better.

DR STEPHEN C. YANG (Baltimore, MD): Rohun, a great job, and also congratulations to Rob. I mentored Rob when he was at Hopkins and he was known for starting the academic versus nonacademic outcomes. So I guess I am your grand mentor. Thanks for making me feel old.

We looked at this readmission recently at our institution. We frequently send patients home, or actually frequently send a nursing follow-up, either they need additional nursing skill sets or they go to a rehabilitation center, and we found that to be actually a very strong predictor of readmissions, about 30%. Did you find that in your data, or is that able to be tracked through the NSQIP?

MR BHAGAT: What happened after discharge?

DR YANG: Yes.

MR BHAGAT: We did find that approximately 80% of people who did have a complication and then were readmitted had a postdischarge complication. So, although we did not present where they were discharged to, we found that patients who did have a postdischarge complication were more likely to be readmitted.