Postoperative day 1 discharge after anatomic lung resection: A Society of Thoracic Surgeons database analysis

Philip A. Linden, MD,^a Yaron Perry, MD,^a Stephanie Worrell, MD,^a Amelia Wallace, MS,^b Luis Argote-Greene, MD,^a Vanessa P. Ho, MD, MPH,^c and Christopher W. Towe, MD^a

ABSTRACT

Objective: Although minimally invasive techniques have led to shorter hospitalizations, discharge on postoperative day 1 is still uncommon. We hypothesized that day 1 discharge could be performed safely and that there might be significant variation in day 1 discharge rates between hospitals.

Methods: We identified patients with lung cancer who underwent lobectomy and segmentectomy in the Society of Thoracic Surgeons Database from 2012 to 2017. The 10% longest hospital stay outliers were excluded. A multivariable regression model was created to assess for factors associated with day 1 discharge and readmission.

Results: A total of 46,325 patients were examined, and 1821 patients (3.9%) were discharged on day 1. This rate increased from 3.4% to 5.3% over the course of the study ($P < .0001$). In multivariable analysis, factors associated with day 1 discharge included age, Zubrod score, body mass index greater than 25, forced expiration value at 1 second, middle or upper lobectomy, minimally invasive technique, and procedure time. Outpatient 30-day mortality was similar (0.3% vs 0.4%, $P = .472$). Patients discharged on day 1 were not at increased risk of readmission. Readmission after day 1 discharge was associated with male sex, coronary artery disease, chronic obstructive pulmonary disease, and longer procedure time. There was substantial variation in day 1 discharge rate between institutions, with 11 centers (4.0%) discharging more than 20% of their patients on day 1, whereas 102 centers (36.7%) had no day 1 discharges.

Conclusions: Day 1 discharge after anatomic lung resection is uncommon but is becoming more common. Carefully selected patients may be discharged on day 1 without an increased risk of readmission or death. (J Thorac Cardiovasc Surg 2020;159:667-78)

Rate of postoperative day 1 discharge after anatomic resection by institution.

Central Message

Postoperative day 1 discharge after lobectomy can be achieved without an increased risk of readmission or death. It can be considered for select patients.

Perspective

Although uncommon (3.9% of patients), postoperative day 1 discharge for select patients after anatomic lung resection can be performed without an increased risk of readmission or death. Significant variability in postoperative day 1 discharge rates between institutions suggests that it may be underused.

See Commentary on page 679.

From the ^aDivision of Thoracic and Esophageal Surgery, Department of Surgery, University Hospitals Cleveland Medical Center and Case Western Reserve School of Medicine, Cleveland, Ohio; ^bDuke Clinical Research Institute, Durham, NC; and ^cDivision of Trauma, Critical Care, Burns, and Acute Care Surgery, Department of Surgery, MetroHealth Medical Center and Case Western Reserve School of Medicine, Cleveland, Ohio.

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Address for reprints: Christopher W. Towe, MD, Division of Thoracic and Esophageal Surgery, University Hospitals Cleveland Medical Center, 11100 Euclid Ave, Cleveland, OH 44106-5011 (E-mail: christopher.towe@uhhospitals.org).

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The average length of stay after thoracoscopic lung resection is 6 days in the United States.¹⁻³ Minimally invasive approaches to lung resection are associated with a reduction in postoperative complications and length of hospital stay.^{4,5} Accelerated care pathways have shown decreased length of stay, but many propose a specific minimum hospitalization.^{6,7} For example, one protocol proposed removing the chest tube on postoperative day 2

Scanning this QR code will take you to the article title page to access supplementary information.

Abbreviations and Acronyms

AOR	= adjusted odds ratio
BMI	= body mass index
ERAS	= enhanced recovery after surgery
GTSD	= General Thoracic Surgery Database
PLOS	= postoperative length of stay
STS	= Society of Thoracic Surgeons

or 3 as a method to reduce length of stay.⁸ Some studies have advocated discharge on the first postoperative day after lung resection and suggest that this approach might be associated with improved outcomes.⁹⁻¹¹ Despite single institution support for postoperative day 1 discharge, this approach has not been studied across institutions or at the national level.

The purpose of this study was to examine the factors associated with postoperative day 1 discharge after anatomic lung resection in the Society of Thoracic Surgeons' Database and to determine whether postoperative day 1 discharge was associated with an elevated risk of readmission or death. We hypothesized that discharge on postoperative day 1 could be performed without an increased risk of readmission or death and that variation in postoperative day 1 discharge may exist between institutions.

MATERIALS AND METHODS

Data Collection and Data Elements

We performed a retrospective cohort study of the Society of Thoracic Surgeons General Thoracic Surgery Database (STS-GTSD). The STS-GTSD is a prospectively maintained database that collects data on patient comorbidities, procedures, and perioperative outcomes. Details of the STS-GTSD data collection instrument and data definitions can be found on the STS website (www.sts.org/sections/stsnationaldatabase). Reporting of cases to the STS-GTSD is voluntary, and as of 2013, the STS-GTSD had an estimated center-level penetration of 25% and patient-level penetration of 38%.¹² Institutional review boards of each participating site approved the use of this database for quality improvement research. In comparison with data from the Centers for Medicare and Medicaid services, STS-participating institutions demonstrated superior perioperative outcomes to nonparticipating institutions, thereby making it an appealing database to study early discharge.¹²

Patient Cohort and Data Analysis

All adult patients undergoing anatomic lung resection by lobectomy or segmental resection for lung cancer from 2012 to 2017 were identified in the STS-GTSD. Exclusion criteria included patients with missing critical study variables (diagnosis, procedure performed, length of stay, readmission within 30 days, perioperative mortality). Patients who died during their index hospitalization were also excluded. Exclusion rules and the effect on the patient cohort are shown in Table E1.

Patients were primarily categorized according to their postoperative length of stay (PLOS), which was defined as the number of "midnights" between their procedure and discharge. This allowed a comparison of patients with early discharge to patients with "average" PLOS.

Other variables extracted from the database included demographics, comorbidities, procedure characteristics, and perioperative outcomes. The primary analysis included univariate analysis of patient and procedural factors associated with postoperative day 1 discharge. Comparisons were made using Pearson chi-square for categorical variables or Wilcoxon rank-sum test for continuous and ordinal variables. Furthermore, a multivariable model including all factors identified in the univariate analysis was used to model the association with odds of postoperative day 1 discharge. To account for center-level clustering of data, the models used generalized estimating equations with independent working correlation. Continuous variables were evaluated before model fit for nonlinearity with the outcomes (postoperative day 1 and readmission within 30 days of discharge). During this process the following factors were found to be nonlinear, and as such splines were created: age, body mass index (BMI), and operating room time. Age was modeled with 2 linear splines with a knot at 68 and was scaled by 5 years (thus, 1 odds ratio is reported for increase by 5 years for patients aged <68 years, and another 1 odds for patients aged ≥68 years). BMI was categorized into the following groups (<18.5, 18.5-<25, 25-<30, 30-<35, 35-<40, ≥40 kg/m²). The operating room time was modeled as 2 linear splines with a knot at 5 hours. Missing values were uncommon and occurred in less than 5% of cases except for diffusing capacity of the lungs for carbon monoxide % (5.6%) and location (lobe) of tumor (6.1%). For the multivariable models, patient factors were imputed to the mode for categorical variables and median for continuous variables.

A secondary analysis was performed to determine if postoperative day 1 discharge was associated with differences in postoperative complications, readmissions, or mortality (within 30 days of discharge). Postoperative complications included in the analysis were unexpected return to the operating room, air leak greater than 5 days, atelectasis requiring bronchoscopy, pleural effusion requiring drainage, pneumonia, respiratory failure, pulmonary embolism, initial ventilator support greater than 48 hours, tracheostomy, reintubation, myocardial infarction, deep venous thrombosis requiring treatment, sepsis, surgical site infection, red cell transfusion, new renal failure, unexpected admission to the intensive care unit, any cardiovascular complication, any urologic complication, any gastrointestinal complication, any neurologic complication, any postoperative event, readmitted to any hospital within 30 days, and perioperative mortality, defined as death within 30 days of the procedure. Major morbidity was defined as pneumonia, acute respiratory distress syndrome, bronchopleural fistula, pulmonary embolus, initial ventilation support greater than 48 hours, reintubation, respiratory failure, tracheostomy, myocardial infarction, or unexpected return to the operating room, based on previous studies.^{13,14} Definitions of events are available from the STS.¹⁵ Comparisons of postoperative complications, readmissions, and mortality were performed using Pearson's chi-square test. Trend analysis of postoperative day 1 discharge rates over time was performed using a Cochrane–Armitage analysis. To characterize patients who were readmitted after postoperative day 1 discharge, we analyzed postoperative day 1 discharge patients who were readmitted compared with those who were not. Comparisons were made using Pearson's chi-square or Wilcoxon rank-sum test, as appropriate. Additionally, we ran a logistic regression model to evaluate the relationship between postoperative day 1 and readmission within 30 days while adjusting for patient factors. This model was fit in the same way as the model described. Because the postoperative day 1 discharge "cutoff" was arbitrary, we also performed a sensitivity analysis to evaluate adverse postoperative events among patients discharged on or before postoperative day 2 compared with patients with longer PLOS (within the 90% percentile as previously). These analyses used identical techniques as described earlier.

On the basis of an a priori hypothesis that factors other than patient factors may affect early discharge, we performed a secondary analysis to determine variation in early discharge rate among institutions. To evaluate differences in postoperative day 1 discharge, the rate of postoperative day 1 discharge was compared by institution. Differences in postoperative day 1 discharge rate by institution were compared visually plotting each centers

FIGURE 1. Histogram of PLOS among nonpneumectomy anatomic lung resections in the STS database. Data shown as percent of patients. Grey bars represent patients excluded from further analysis because of being in the 10% longest hospital length of stay.

postoperative day 1 rate along with error bars representing their 95% Clopper-Pearson exact confidence interval. Data analysis was performed using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

During the study period, there were 51,078 lung resections that met study inclusion criteria, performed at 278

centers. The distribution of hospital length of stay is shown in [Figure 1](#). The overall median PLOS was 4 days. There were 1585 patients (3.6%) discharged on postoperative day 1. The rate of postoperative day 1 discharge increased over the study, increasing from 3.4% in 2012 to 5.3% in 2017 (Cochran–Armitage Trend Z statistic = -4.84 ; 1 sided $Pr < Z$, $<.0001$; 2-sided $Pr > Z$, $<.0001$) ([Figure 2](#)). Ninety percent of patients were discharged by postoperative day 9, and patients with PLOS longer than 9 days were excluded from further analysis, yielding a total of 46,325 patients.

Patients discharged on postoperative day 1 differed from patients with longer PLOS in several ways ([Table 1](#)). Compared with patients discharged between postoperative days 2 and 9, patients discharged on postoperative day 1 tended to be younger, to be white, to have a higher BMI, to have higher percent predicted forced expiratory volume in 1 second, to have higher percent predicted diffusing capacity of the lungs for carbon monoxide, to have a lower American Society of Anesthesiologists classification, and to have lower Zubrod score. Patients discharged on postoperative day 1 also had lower rates of hypertension, coronary artery disease, peripheral vascular disease, and chronic obstructive pulmonary disease. The procedures themselves were less likely to have been a lobectomy, more likely to have been minimally invasive, and had shorter procedure and operating room times. In the multivariable model ([Table 2](#)), factors associated with an increased odds of postoperative day 1 discharge were BMI 25 or greater, preoperative steroid use (adjusted odds ratio [AOR], 1.44,

FIGURE 2. Rate of postoperative day 1 discharge relative to discharge between postoperative day 2 and postoperative day 9 (%) by year. Error bars represent 95% confidence intervals. The rate of postoperative day 1 discharge increased during the study period ($P < .0001$).

TABLE 1. Description of cohort comparing differences in postoperative length of stay

Effect	Overall N = 46,325	Postoperative day 1 discharge n = 1821	Normal discharge n = 44,504	P value
Age				
Median (IQR)	68.0 (61.0-74.0)	66.0 (59.0-73.0)	68.0 (61.0-74.0)	<.0001
Sex				
Male	19,953 (43.1%)	773 (42.4%)	19,180 (43.1%)	.5836
Female	26,371 (56.9%)	1048 (57.6%)	25,323 (56.9%)	
BMI (kg/m ²)				
Median (IQR)	27.0 (23.7-31.0)	27.4 (24.1-31.4)	27.0 (23.6-30.9)	.0025
Hypertension	28,273 (61.0%)	1047 (57.5%)	27,226 (61.2%)	.0003
Steroids	1357 (2.9%)	67 (3.7%)	1290 (2.9%)	.0732
Congestive heart failure	1191 (2.6%)	36 (2.0%)	1155 (2.6%)	.0922
Coronary artery disease	9324 (20.1%)	290 (15.9%)	9034 (20.3%)	<.0001
Peripheral vascular disease	3867 (8.3%)	110 (6.0%)	3757 (8.4%)	.0002
Diabetes mellitus	8641 (18.7%)	323 (17.7%)	8318 (18.7%)	.2439
Chronic obstructive pulmonary disease	16,360 (35.3%)	544 (29.9%)	15,816 (35.5%)	<.0001
FEV1 % predicted				
Median (IQR)	84.0 (71.0-98.0)	88.0 (75.0-100.0)	84.0 (71.0-98.0)	<.0001
Diffusing capacity of the lungs for carbon monoxide % predicted				
Median (IQR)	74.0 (60.0-88.0)	78.0 (64.0-91.0)	74.0 (60.0-88.0)	<.0001
American Society of Anesthesiologists Risk Class				
I	128 (0.3%)	7 (0.4%)	121 (0.3%)	<.0001
II	7327 (15.8%)	360 (19.8%)	6967 (15.7%)	
III	35,239 (76.1%)	1357 (74.5%)	33,882 (76.1%)	
IV	3590 (7.7%)	97 (5.3%)	3493 (7.8%)	
≥V	27 (0.0%)	0 (0.0%)	27 (0.0%)	
Zubrod score				
Normal activity, no symptoms	21,237 (45.8%)	1030 (56.6%)	20,207 (45.4%)	<.0001
Symptoms but fully ambulatory	23,238 (50.2%)	752 (41.3%)	22,486 (50.5%)	
Symptoms but in bed <50% of the time	1493 (3.2%)	33 (1.8%)	1460 (3.3%)	
Symptoms but in bed >50% but <100%	301 (0.6%)	5 (0.3%)	296 (0.7%)	
Bedridden	36 (0.1%)	1 (0.1%)	35 (0.1%)	
Moribund	5 (0.0%)	0 (0.0%)	5 (0.0%)	
Laterality				
Right	25,985 (56.1%)	1015 (55.7%)	24,970 (56.1%)	.6401
Left	18,425 (39.8%)	729 (40.0%)	17,696 (39.8%)	
Bilateral	46 (0.1%)	3 (0.2%)	43 (0.1%)	
Tumor location - lobe				
Upper	25,496 (55.0%)	865 (47.5%)	24,631 (55.3%)	<.0001
Middle	3025 (6.5%)	193 (10.6%)	2832 (6.4%)	
Lower	14,978 (32.3%)	555 (30.5%)	14,423 (32.4%)	
Lobectomy				
Segmental resection	4888 (10.6%)	327 (18.0%)	4561 (10.2%)	<.0001
Lobectomy	41,437 (89.4%)	1494 (82.0%)	39,943 (89.8%)	
Minimally invasive technique	31,898 (68.9%)	1669 (91.7%)	30,229 (67.9%)	<.0001
OR time (min)				
Median (IQR)	238.0 (188.0-298.0)	193.0 (158.0-238.0)	240.0 (190.0-300.0)	<.0001

(Continued)

TABLE 1. Continued

Effect	Overall N = 46,325	Postoperative day 1 discharge n = 1821	Normal discharge n = 44,504	P value
PRBCs transfused intraoperatively	745 (1.6%)	4 (0.2%)	741 (1.7%)	<.0001
No. of PRBCs transfused				
Median (IQR)	2.0 (1.0-2.0)	2.5 (1.0-4.5)	2.0 (1.0-2.0)	.6543

Patients with postoperative day 1 discharge compared with patients discharged from postoperative day 2 to 9 (“normal discharge”). Data presented as number (%) or median and IQR. Comparison of groups performed using chi-square, Wilcoxon rank-sum, or Kruskal–Wallis test, as appropriate. IQR, Interquartile range; BMI, body mass index; FEV1, forced expiratory volume in 1 second; OR, operating room; PRBCs, packed red blood cells.

$P = .0263$), higher forced expiratory volume in 1 second % predicted (AOR, 1.03, $P = .0024$ per 5% increase), location of operation in the middle lobe (vs upper lobe, AOR, 1.58, $P < .0001$), and use of minimally invasive versus open (AOR, 4.74, $P < .0001$). Factors associated with a decrease in the odds of early discharge were older age (<68 years, AOR, 0.93, $P = .0001$, per 5-year increase; ≥ 68 years, AOR, 0.87, $P < .0001$, per 5-year increase), female sex (AOR, 0.77, $P < .0001$), Zubrod score of 2 versus 0 (AOR, 0.52, $P = .0021$), location of the operation in the lower lobe (vs upper lobe, AOR, 0.84, $P = .0035$), lobectomy (vs segmentectomy, AOR, 0.62, $P = .0180$), and longer operating room time in the first 5 hours (AOR, 0.57, $P < .0001$, per hour increase). Operative time longer than 5 hours was not associated with any additional decrease in the odds of early discharge.

In regard to postoperative events, postoperative day 1 patients had fewer overall complications (11.9% vs 33.2%, $P < .0001$) or major morbidity (1.3% vs 4.2%, $P < .0001$). (Table E2). Postdischarge mortality rates were equivalent between postoperative day 1 discharge and those discharged between postoperative days 2 and 9 (0.3% vs 0.4%, $P = .472$). Unadjusted readmission rates within 30 days of discharge were lower in patients discharged on postoperative day 1 (6.3% vs 7.8%, $P = .014$). To account for possible confounding of patient variables in readmission rates, we performed a multivariable regression (Table 3), which showed no increased risk of readmission among patients discharged on postoperative day 1. The variables associated with readmission, including odds ratios, are displayed in Table 3. The rate of patients discharged with a chest tube on postoperative day 1 was 5.8% and was lower than for patients discharged between postoperative days 2 and 9 (7.7%, $P < .001$). Sensitivity analysis showed that patients discharged on postoperative day 2 were less likely to have any complication (11.6% vs 36.9%, $P < .0001$) and major morbidity (1.1% vs 4.4%, $P < .0001$). In this analysis, mortality rate was also similar to longer PLOS (0.3% vs 0.4%, $P = .206$).

Rate of postoperative day 1 discharge varied by institution, and variability by center is shown in Figure 3. Eleven centers (11/278, 4.0%) discharged more than 20% of their patients on postoperative day 1, and 102 centers (102/278

36.7%) had no postoperative day 1 discharges. Twenty-eight centers (10.1%) had statistically higher postoperative day 1 discharge rates compared with others, and 84 centers (30.2%) had below average rates of postoperative day 1 discharge.

DISCUSSION

Appropriate resource allocation should minimize hospital length of stay while maintaining low rates of readmission and complications. Shorter length of stays may also be associated with lower rates of hospital acquired conditions, such as nosocomial pneumonia and deep venous thrombosis.¹⁶ These factors have driven the adoption of enhanced recovery after surgery (ERAS) after thoracic surgery.^{7,8,17} Enhanced recovery pathways have not met universal success,¹⁸ and compliance has been shown to be a key factor with benefit from ERAS protocols.¹⁹ We and others have demonstrated, in single institution reports, that safe discharge after lobectomy on postoperative day 1 is possible.⁶ In this STS database study, patients discharged on postoperative day 1 after anatomic lung resection do not have an increased rate of readmission. Likewise, outpatient 30-day mortality was similar between the 2 groups. The main findings of our study are summarized in the Figure 4.

Safe, routine discharge on postoperative day 1 is contingent on appropriate patient selection, and inappropriate use of postoperative day 1 discharge may result in serious patient harm or death. In this analysis, we report several factors associated with early discharge, including age, comorbidities, and surgical factors such as approach and operative duration. Preoperative steroid use was, unexpectedly, linked to postoperative day 1 discharge. Steroids are useful in treating and preventing chronic obstructive pulmonary disease exacerbations, and, perhaps, in this regard they were beneficial. In multivariable regression, patient factors and operative approach remained significant drivers of postoperative day 1 discharge, with minimally invasive approach (vs open), and operative duration demonstrating the strongest relationship. Other factors, not measured in this study, including support available at home and distance between home and the hospital should also be factored into the decision to discharge on postoperative day 1. Although no cutoff criteria for early discharge were derived from this

TABLE 2. Factors associated with postoperative day 1 discharge relative to patients discharged between day 2 and 9 in univariate (unadjusted) and multivariate regression models (adjusted)

Cofactor	Category	Unadjusted		Adjusted	
		OR (95% CI)	P value	OR (95% CI)	P value
Age, per 5-y increase	<68	0.92 (0.89-0.95)	<.0001	0.93 (0.89-0.96)	.0001
	≥68	0.86 (0.82-0.91)	<.0001	0.87 (0.81-0.92)	<.0001
Sex, female		1.03 (0.93-1.13)	.5946	0.77 (0.70-0.85)	<.0001
BMI	<18.5	0.92 (0.71-1.20)	.5450	1.06 (0.80-1.41)	.6779
	18.5-24.9	Ref.		Ref.	
	25-29.9	1.06 (0.96-1.17)	.2866	1.22 (1.10-1.36)	.0002
	30-34.9	1.03 (0.93-1.15)	.5755	1.25 (1.08-1.43)	.0020
	35-39.9	1.11 (0.91-1.34)	.3099	1.40 (1.09-1.78)	.0072
	≥40	1.20 (0.90-1.60)	.2184	1.70 (1.25-2.33)	.0009
Hypertension		0.86 (0.76-0.97)	.0174	0.95 (0.83-1.09)	.4670
Preoperative steroids		1.28 (0.92-1.78)	.1435	1.44 (1.04-1.98)	.0263
Congestive heart failure		0.76 (0.48-1.19)	.2275	0.93 (0.59-1.47)	.7586
Coronary artery disease		0.74 (0.63-0.87)	.0003	0.86 (0.72-1.03)	.0976
Peripheral vascular disease		0.70 (0.53-0.92)	.0107	0.83 (0.63-1.09)	.1761
Diabetes		0.94 (0.82-1.07)	.3464	1.04 (0.90-1.19)	.6206
Chronic obstructive pulmonary disease		0.77 (0.60-1.00)	.0487	0.92 (0.71-1.20)	.5520
FEV1 % predicted, per 5% increase		1.04 (1.02-1.06)	<.0001	1.03 (1.01-1.04)	.0024
ASA classification	1-2	Ref.		Ref.	
	3-5	0.75 (0.62-0.90)	.0023	1.04 (0.84-1.28)	.7183
Zubrod score	0	Ref.		Ref.	
	1	0.69 (0.54-0.88)	.0031	0.79 (0.60-1.03)	.0822
	2	0.54 (0.38-0.78)	.0008	0.52 (0.34-0.79)	.0021
	3-5	0.43 (0.12-1.62)	.2149	0.36 (0.10-1.38)	.1381
Laterality	Left	Ref.		Ref.	
	Right/bilateral	0.99 (0.91-1.08)	.7933	0.94 (0.86-1.03)	.1827
Lobe	Upper	Ref.		Ref.	
	Middle	1.74 (1.45-2.09)	<.0001	1.58 (1.26-1.98)	<.0001
	Lower	0.91 (0.82-1.02)	.0991	0.84 (0.75-0.95)	.0035
Lobectomy		0.52 (0.37-0.73)	.0001	0.62 (0.42-0.92)	.0180
Minimally invasive technique		5.19 (3.46-7.77)	<.0001	4.74 (3.12-7.20)	<.0001
Intraoperative PRBCs		0.13 (0.05-0.37)	.0001	0.45 (0.16-1.29)	.1377
Operating room time, per hour	<5 h	0.55 (0.45-0.66)	<.0001	0.57 (0.46-0.71)	<.0001
	≥5 h	0.42 (0.29-0.61)	<.0001	0.82 (0.66-1.01)	.0623

Data presented as OR and 95% CI. Cofactors for model were selected from univariate model (Table 1). OR, Odds ratio; CI, confidence interval; BMI, body mass index; FEV1, forced expiratory volume in 1 second; ASA, American Society of Anesthesiologists; PRBCs, packed red blood cells.

analysis, these findings suggest that ERAS pathways may benefit from individualized patient selection, with the lowest risk patients placed into a fast track to discharge. Realistically, enhanced recovery pathways should be individualized to certain expectations, such that patients with higher risks of perioperative events or readmission might receive specialized preventative care while patients with low risk of events could be identified and safely discharged early.

Thoracic surgery has been relatively slow to adapt practice patterns in conjunction with advances in minimally invasive techniques. For example, a study of the Premier Database showed that less than 40% of lobectomies in the United States were performed using video-assisted thoracoscopic surgery technique, and that video-assisted thoracoscopic surgery lobectomy rates were unchanged in many areas of the United States during the study period.³ In general surgery, minimally invasive technique have led to

TABLE 3. Multivariable regression for odds of readmission by discharge time (postoperative day 1 vs discharge between postoperative days 2 and 9)

Outcome	Category	Unadjusted		Adjusted	
		OR (95% CI)	P value	OR (95% CI)	P value
Postoperative day 1		0.79 (0.64-0.97)	.0239	0.94 (0.76-1.16)	.5379
Age, per 5-y increase	<68	1.05 (1.02-1.07)	.0005	0.99 (0.96-1.02)	.4766
	≥68	1.08 (1.04-1.12)	<.0001	1.08 (1.03-1.13)	.0010
Sex, female		0.79 (0.74-0.84)	<.0001	0.87 (0.81-0.93)	<.0001
BMI	<18.5	1.20 (0.99-1.46)	.0643	1.04 (0.85-1.27)	.6899
	18.5-24.9	Ref.		Ref.	
	25-29.9	0.90 (0.83-0.98)	.0104	0.81 (0.74-0.88)	<.0001
	30-34.9	0.91 (0.84-0.99)	.0336	0.78 (0.71-0.85)	<.0001
	35-39.9	0.94 (0.82-1.08)	.3778	0.79 (0.68-0.90)	.0008
	≥40	1.07 (0.88-1.30)	.4911	0.88 (0.72-1.08)	.2207
Hypertension		1.18 (1.09-1.27)	<.0001	1.04 (0.96-1.12)	.3286
Preoperative steroids		1.48 (1.25-1.76)	<.0001	1.35 (1.13-1.60)	.0007
Congestive heart failure		1.41 (1.13-1.76)	.0027	1.07 (0.85-1.34)	.5633
Coronary artery disease		1.42 (1.31-1.53)	<.0001	1.18 (1.08-1.28)	.0002
Peripheral vascular disease		1.52 (1.37-1.68)	<.0001	1.21 (1.09-1.34)	.0003
Diabetes		1.15 (1.06-1.25)	.0007	1.06 (0.97-1.15)	.2161
Chronic obstructive pulmonary disease		1.47 (1.36-1.59)	<.0001	1.24 (1.15-1.35)	<.0001
FEV1 % predicted, per 5% increase		0.96 (0.95-0.97)	<.0001	0.98 (0.97-0.99)	.0004
ASA classification	1-2	Ref.		Ref.	
	3-5	1.55 (1.37-1.75)	<.0001	1.25 (1.09-1.43)	.0015
Zubrod score	0	Ref.		Ref.	
	1	1.22 (1.13-1.32)	<.0001	1.14 (1.05-1.23)	.0010
	2	1.35 (1.09-1.67)	.0050	1.26 (1.01-1.56)	.0411
	3-5	1.72 (1.20-2.44)	.0028	1.61 (1.12-2.31)	.0095
Laterality	Left	Ref.		Ref.	
	Right/bilateral	1.05 (0.97-1.13)	.2236	1.09 (1.01-1.17)	.0250
Lobe	Upper	Ref.		Ref.	
	Middle	0.75 (0.64-0.88)	.0004	0.77 (0.65-0.91)	.0028
	Lower	1.13 (1.05-1.22)	.0016	1.15 (1.06-1.25)	.0007
Lobectomy		1.11 (0.98-1.27)	.1022	1.14 (1.00-1.30)	.0508
Minimally invasive technique		0.81 (0.75-0.88)	<.0001	0.87 (0.80-0.95)	.0013
Intraoperative PRBCs		1.67 (1.34-2.08)	<.0001	1.26 (1.01-1.57)	.0387
Operating room time, per hour	<5 h	1.08 (1.02-1.14)	.0070	1.02 (0.96-1.07)	.5675
	≥5 h	1.14 (1.09-1.20)	<.0001	1.09 (1.04-1.15)	.0004

OR, Odds ratio; CI, confidence interval; BMI, body mass index; FEV1, forced expiratory volume in 1 second; ASA, American Society of Anesthesiologists; PRBCs, packed red blood cells.

dramatic changes in practice. For example, the transition from open cholecystectomy to laparoscopic technique was associated with a decrease from 5- to 7-day hospitalization to a 1- to 1.5-day PLOS.^{20,21} Roux-en-Y gastric bypass as an open procedure was associated with 4- to 8-day hospitalizations, but ERAS pathways and minimally invasive techniques have been associated with successful discharge on

postoperative day 1.^{22,23} Thoracoscopic techniques in lung lobectomy have not demonstrated such a dramatic effect on duration of hospitalization.²⁴ The first large randomized trial of thoracoscopic versus open lung resection did not show a benefit in reducing length of stay.²⁵ More recent reports suggest that thoracoscopic lobectomy is associated with a reduction in length of stay to 4 to 5 days

FIGURE 3. Caterpillar graph of variation in postoperative day 1 discharge rate among 278 institutions participating in the STS-GTSD. Data presented as rate of postoperative day 1 discharge (%) and 95% confidence interval. *Red* represents “below average” rate of postoperative day 1 discharge. (n = 84/278), *blue* “average” rate of postoperative day 1 discharge, and *green* represents “above average” rate (n = 28/278).

compared with 6 to 7 days with thoracotomy.^{5,26} Routine use of postoperative day 1 discharge in appropriate patients could significantly decrease PLOS. This study demonstrated that a relatively small number of institutions

are leading the process of reducing hospitalization through postoperative day 1 discharge.

There are multiple barriers to early discharge after lung resection. This study corroborates that patients undergoing

Postoperative Day One Discharge (POD1 DC) Following Anatomic Lung Resection: An STS Database Analysis

FIGURE 4. Postoperative day 1 discharge is uncommon, but increasing. It is not associated with hospital readmission. There is significant variation in use of postoperative day 1 discharge between hospitals. *STS*, Society of Thoracic Surgeons.

VIDEO 1. Key findings and conclusions of this study by Dr Philip A. Linden. Video available at: [https://www.jtcvs.org/article/S0022-5223\(19\)31773-8/fulltext](https://www.jtcvs.org/article/S0022-5223(19)31773-8/fulltext).

lung surgery have significant comorbidities, which may mandate prolonged inpatient care. Patient comorbidities may also affect adherence to ERAS pathways, further limiting their ability to be discharged.¹⁹ Technical aspects of the procedures are also critical to early discharge. A minimally invasive approach was strongly associated with postoperative day 1 discharge (odds ratio, 4.74), suggesting that barriers to adopting minimally invasive technique will, in turn, affect postoperative day 1 discharge. In addition to minimally invasive techniques, methods to reduce postoperative air leak, such as fissureless dissection, are also likely beneficial in reducing PLOS.²⁷⁻²⁹ Pain control is also a factor in duration of hospitalization, and difficulties in perioperative pain control are also likely a barrier to postoperative day 1 discharge.³⁰ Methods to minimize pain during surgery, such as minimally invasive technique, and intraoperative pain modalities, such as lyophilized bupivacaine or intercostal nerve cryotherapy, may be helpful in facilitating early discharge.

Significant center variation in postoperative day 1 discharge rates suggest that ingrained practice patterns may be a barrier to postoperative day 1 discharge. Differences in patient acuity and complexity of operation certainly may account for some of the center variation, with centers operating on sicker patients, surgeons performing more complex operations, or patients traveling a great distance to their hospital, less likely to discharge a patient on day 1. The finding that 37% of centers did not send even a single patient home on postoperative day 1, whereas 11 centers sent more than 20% of patients with anatomic resections home on postoperative day 1, strongly suggests that some centers do not even consider postoperative day 1 discharge. Awareness that postoperative day 1 discharge can be considered in selected patients without an increase in readmission rate or mortality may help change these practice patterns.

Study Limitations

This retrospective study has several limitations. First, although complications were fewer in patients discharged

on postoperative day 1, no conclusions can be made as to whether postoperative day 1 discharge resulted in fewer complications or whether the absence of complications in the first 24 hours resulted in more postoperative day 1 discharges. Overall, patients being discharged on postoperative day 1 were younger and healthier than patients discharged later, making comparisons regarding incidence of complications difficult. Second, the study spans several years and hundreds of surgeons, whose preferences and techniques may have varied over time, and details of perioperative care are not available. Therefore, provider judgment and institutional experience are significant confounders in the decision regarding timing of discharge. Details of which criteria and cutoffs are essential for safe postoperative day 1 discharge cannot be quantified by this study. This study was also an analysis of STS-participating institutions, whose outcomes have been shown to be superior to the general population,¹² which may limit the generalizability of these findings.

CONCLUSIONS

Patients selected for postoperative day 1 discharge were, on average, younger and healthier than patients discharged after postoperative day 1. In this study, postoperative day 1 discharge after anatomic lung resection was not associated with increased risks of readmission or death. Surgeon preference and institutional factors are likely a significant determinant of early discharge (Video 1). Further studies are necessary to identify patient and institutional factors necessary for safe postoperative day 1 discharge and define enhanced recovery protocols that may allow routine postoperative day 1 discharge.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://aats.blob.core.windows.net/media/19%20AM/Monday_May6/203BD/203BD/S89%20-%20Doing%20the%20right%20thing%20II/S89_7_webcast_054148789.mp4.

Conflict of Interest Statement

Dr Towe reports that he is a consultant for Zimmer Biomet, Sig Medical, AtriCure, and Medtronic, but that these relationships have not affected this manuscript or the accuracy of the data analysis. All other authors have nothing to disclose with regard to commercial support.

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Key Words: length of stay, patient discharge, postoperative complications, risk factors, thoracic surgery

Discussion

Dr Benjamin D. Kozower (St. Louis, Mo). Congratulations to you and your team for performing a thoughtful and hypothesis-generating study. The thoracic surgery community continues to face increased pressure to perform these complicated anatomic lung resections in a minimally invasive fashion

with extremely low complication rates and to further reduce our resource use. Sending a patient home on postoperative day 1 after a lobectomy or segmentectomy would have been unheard of when the STS thoracic database was started almost 20 years ago. Your results demonstrate a median length of stay of 4 days, about a 3.6% rate of discharge on postoperative day 1 for the entire series, and the hospital variation for early discharge on postoperative day 1 is impressive, and I think not so unexpected. I have 3 questions for you.

First, did you examine the discharge location for these patients and whether or not they were discharged with a chest tube in place? Both of these variables are included in the STS database, and I think it is important.

Dr Christopher W. Towe (Cleveland, Ohio). Yes, we did look at that, and 99% of patients in the day 1 group were discharged to home. The STS doesn't have a category for the hotel across the street. I think there is some gut reaction that perhaps this is happening, but taking the data as they

are, the majority go home. Twelve were discharged to a

rehab facility, which is surprising to me. But generally they are going home.

In terms of chest tube rate, there were 6% of patients discharged with a chest tube in the day 1 group. This was significantly less than the normal discharge group, which was 7.5%, and I think is a perplexing problem. I would certainly rather keep a patient in the hospital for a day and get the tube out, for a variety of reasons, really, but the data are what they are.

Dr Kozower. My second question is, your data also demonstrate that a patient was more likely to be discharged on day 1 after a segmentectomy than a lobectomy. That surprised me and has not been my own personal experience. As I thought about it, I was concerned. Are some of these segmentectomies in our database glorified wedge resections? So another thing that could be looked at and potentially something you could do in the future, when you looked at these segmentectomies, were they really adequate lung cancer operations that actually sample N1 and N2 nodes?

Dr Towe. It is an excellent question, and I have thought about it, too, in that in an unadjusted way you would hope that segmentectomies might balance in poor lung function, but in the adjusted analysis, there was still a relationship. So I am surprised that the prevalence of some segmentectomies is occurring like that. My hypothesis is that they are probably small tumors in the tip of the superior segment or things like that and they are highly selected cases.

When I take a step back from the data, the thing that strikes me the most is operative time per hour, and my guess is that it's the easiest segments, not the ones where you are sort of chiseling through the hilum to find a perforating branch of an artery that are the ones that are the best candidates to go home.

Dr Kozower. How will you and your team use these results going forward and do you have any plans to study this, particularly from the patient perspective?

Dr Towe. There are a lot of questions that this study generates, at least for us. How can we increase use of day 1 discharge among the low performers? In other words, what can the low performers learn from the high performers? A rising tide lifts all of us, right? So, we would like to initiate a national study of which aspects of an ERAS protocol at the high performers could be instituted elsewhere.

We would also like to look at which aspects of patient selection could be used to tailor patients into different ERAS protocols. Ultimately, a 1-size-fits-all ERAS protocol doesn't make any sense. The patients who were at higher risk in the 2008 Wright study for 14-day length of stays should get a different protocol than the patients who are going home tomorrow. They shouldn't all be treated the same.

Your question about patient-centered outcomes is also interesting. We would love to know more about what patients want out of their hospitalizations. Currently we assume it's to go home, but I think that has a lot to do with building the expectations or engendering a sense that going home is the safest thing for them. As Phil Linden alluded to earlier, early preoperative education so that expectations are met.

Unidentified Speaker. I think you actually were alluding to a question that I had regarding the early presentation, too, from Dr Park. So obviously preoperative education is important in setting expectations, but what do you do postoperatively? How do you educate the patients and the families? What protocols do you have in place to prevent patients from being readmitted?

Dr Towe. At our institution, I think the realization that day 1 discharge is safe has shed new light on the opportunity for certain patients to do that. I think there are protocols floating around in each of our minds about chest tubes being left in for 2 days or on suction for day 1 and water seal for day 2. So, what we are trying to do is shift that whole expectation.

With that also comes things like phone calls to patients after they are discharged, staying in communication and not letting them feel like being discharged is like breaking up with someone, but the relationship continues after they go home so that they are not left in the lurch. Those communications can head off a readmission or a problem like a late complication more so than keeping someone in the hospital and watching them very closely.

Unidentified Speaker. What is your postoperative follow-up time?

Dr Towe. We routinely see patients within 3 weeks of discharge. It depends on, sort of, the clinic day to operating room day gap. But we tend to see patients at 2 weeks, for pneumonectomy patients, again, at 6 weeks, and then after that sort of on an as-needed basis.

Dr Susan D. Moffatt-Bruce (*Columbus, Ohio*). Would you alter your protocol should you adopt a postoperative day number 1 discharge from 3 weeks to maybe 7 days?

Dr Towe. These data would suggest that the patients who had day 1 discharge probably don't need follow-up. They are probably going to do fine whether you see them or not. So the concept is that I think we still believe that we need to keep these patients very close to the chest, but I think the irony, of course, is that they are the patients who are least likely to have problems. We have preselected them in a way that not only are they the healthiest people but also we have done the simplest operation we can do on them.

Dr Dirk Van Raemdonck (*Leuven, Belgium*). In the patients who were discharged on day 1, do you have any idea from the database whether they underwent operation in the morning or in the afternoon, because there is a difference of 12 hours.

Dr Towe. We were forced to calculate the number of midnights between admission and discharge. I know some hospitals would calculate this based on a 24-hour cycle. So there is some variability in what that means based on time of surgery versus time of discharge, and that's a potential limitation but within the realm of what I think makes sense.

Dr Moffatt-Bruce. The Chair's prerogative: Dr Kneuert, do you have any comments? You have

been my partner who has been sending some of his patients home on postoperative day number 1. Any additional comments as to what you do differently to keep these patients safe and still have a low readmission rate?

Dr Peter Jens Achim Kneuert (*Columbus, Ohio*). I would echo what the other attendees have said. Setting expectations is probably the most important thing going forward. It does have to do with the approach. I think the smaller the incisions and the less long the operation is, the better the chance

we have for a fast recovery. We should all strive to continue to decrease the patient's length of stay.

Readers who found these articles interesting may also like to read the following papers found in recent and future issues of our sister publications, *Seminars in Thoracic and Cardiovascular Surgery* and *Operative Techniques in Thoracic and Cardiovascular Surgery*!

Thoracic: Lung Cancer

STCVS: Subxiphoid Uniportal VATS for Thymic and Combined Mediastinal and Pulmonary Resections – A Two-Year Experience. Abu-Akar F, Gonzalez-Rivas D, Yang C, Lin L, Wu L, Jiang L. *Semin Thorac Cardiovasc Surg.* 2019;31(3):614-619.

Commentary: The Ongoing Debate on the Ideal Approach to Thymectomy. Figueroa PU. *Semin Thorac Cardiovasc Surg.* 2019;31(3):620-621.

TABLE E1. Exclusion criteria and the effect on cohort: Data presented as number of patients (or centers)

Exclusion rules applied	Operations excluded	Remaining operations	Remaining centers
1-Surgery year: 2012-2017	0	218,011	283
2-Adult patients: aged ≥ 18 y	1264	216,747	283
3-Anatomic lung resection (lobectomy and segmentectomy)	152,873	63,874	281
4-Lung cancer diagnosis	9316	54,558	279
4-Exclude: Patients who died during index hospitalization	452	54,106	279
5-Exclude: Patients missing critical study variables	3028	51,078	278

TABLE E2. Comparison of postoperative complications by duration of hospitalization

Postoperative complication	Effects	Postoperative day 1			P value
		Overall N = 46,325	discharge n = 1821	Normal discharge n = 44,504	
Any postoperative events	Yes	14,982 (32.3%)	217 (11.9%)	14,765 (33.2%)	<.0001
Any major complications	Yes	1887 (4.1%)	23 (1.3%)	1864 (4.2%)	<.0001
Air leak >5 d	Yes	3628 (7.8%)	36 (2.0%)	3592 (8.1%)	<.0001
Atelectasis requiring bronchoscopy	Yes	885 (1.9%)	8 (0.4%)	877 (2.0%)	<.0001
Pneumonia	Yes	816 (1.8%)	11 (0.6%)	805 (1.8%)	.0001
Adult respiratory distress syndrome	Yes	40 (0.1%)	0 (0.0%)	40 (0.1%)	.2004
Respiratory failure	Yes	390 (0.8%)	3 (0.2%)	387 (0.9%)	.0012
Bronchopleural fistula	Yes	65 (0.1%)	0 (0.0%)	65 (0.1%)	.1025
Pulmonary embolus	Yes	154 (0.3%)	2 (0.1%)	152 (0.3%)	.0919
Pneumothorax requiring CT reinsertion	Yes	1070 (2.3%)	29 (1.6%)	1041 (2.3%)	.0372
Initial ventilatory support >48 h	Yes	28 (0.1%)	0 (0.0%)	28 (0.1%)	.2841
Reintubation	Yes	179 (0.8%)	3 (0.4%)	176 (0.8%)	.1627
Tracheostomy	Yes	20 (0.0%)	1 (0.1%)	19 (0.0%)	.8063
Atrial arrhythmia requiring treatment	Yes	4158 (9.0%)	31 (1.7%)	4127 (9.3%)	<.0001
Deep venous thrombosis	Yes	113 (0.2%)	1 (0.1%)	112 (0.3%)	.0950
Empyema requiring treatment	Yes	134 (0.3%)	0 (0.0%)	134 (0.3%)	.0190
Chylothorax requiring medical intervention	Yes	125 (0.3%)	1 (0.1%)	124 (0.3%)	.0710
Unexpected admission to ICU	Yes	783 (1.7%)	7 (0.4%)	776 (1.7%)	<.0001
Myocardial infarction	Yes	73 (0.2%)	0 (0.0%)	73 (0.2%)	.0836
Recurrent laryngeal nerve Paresis/paralysis	Yes	131 (0.3%)	2 (0.1%)	129 (0.3%)	.1556
Pleural effusion requiring drainage	Yes	495 (1.1%)	5 (0.3%)	490 (1.1%)	.0008
Tracheobronchial injury	Yes	5 (0.0%)	0 (0.0%)	5 (0.0%)	.6375
Another pulmonary event	Yes	1194 (2.6%)	17 (0.9%)	1177 (2.6%)	<.0001
Ventricular arrhythmia requiring treatment	Yes	166 (0.4%)	1 (0.1%)	165 (0.4%)	.0270
Other cardiovascular event	Yes	499 (1.1%)	4 (0.2%)	495 (1.1%)	.0003
Unexpected return to the OR	Yes	748 (1.6%)	11 (0.6%)	737 (1.7%)	.0005
<i>Clostridium difficile</i> infection	Yes	38 (0.2%)	1 (0.1%)	37 (0.2%)	.6198
Other GI event	Yes	278 (0.6%)	3 (0.2%)	275 (0.6%)	.0141
Packed red blood cells transfused	Yes	1110 (2.4%)	5 (0.3%)	1105 (2.5%)	<.0001
Urinary tract infection	Yes	748 (1.6%)	10 (0.5%)	738 (1.7%)	.0002
Urinary retention requiring catheterization	Yes	2549 (5.5%)	59 (3.2%)	2490 (5.6%)	<.0001
Discharged with Foley catheter	Yes	481 (1.0%)	33 (1.8%)	448 (1.0%)	.0009
Surgical site infection	Superficial	221 (0.5%)	5 (0.3%)	216 (0.5%)	.3945
	Deep	28 (0.1%)	1 (0.1%)	27 (0.1%)	
	Organ space	32 (0.1%)	0 (0.0%)	32 (0.1%)	
Sepsis	Yes	89 (0.2%)	2 (0.1%)	87 (0.2%)	.4126
Other infection	Yes	319 (0.7%)	5 (0.3%)	314 (0.7%)	.0290
New central neurologic event	Yes	126 (0.3%)	4 (0.2%)	122 (0.3%)	.6600
Delirium	Yes	728 (1.6%)	4 (0.2%)	724 (1.6%)	<.0001
Other neurologic event	Yes	173 (0.4%)	2 (0.1%)	171 (0.4%)	.0596
New renal failure per RIFLE criteria	Yes	103 (0.2%)	2 (0.1%)	101 (0.2%)	.2968
Other events requiring OR with General anesthesia	Yes	213 (0.5%)	5 (0.3%)	208 (0.5%)	.2626
Operative mortality	Yes	174 (0.4%)	5 (0.3%)	169 (0.4%)	.4721
Readmission within 30 d of Discharge	Yes	3599 (7.8%)	114 (6.3%)	3485 (7.8%)	.0141

P values are based on comparison of patients with postoperative day 1 discharged compared with patients discharged between day 2 and 9 using chi-square test. CT, Computed tomography; ICU, intensive care unit; OR, operating room; GI, gastrointestinal; RIFLE, Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease classification.