Postoperative day 1 discharge following robotic thoracoscopic pulmonary anatomic resections in the era of enhanced recovery protocol: A single-institution experience

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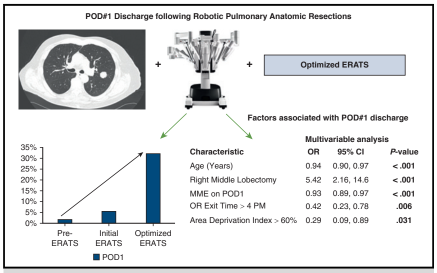
ABSTRACT

Objective: Implementation and continuing optimization of enhanced recovery protocol after thoracic surgery results in significant improvement of postoperative outcomes. We observed a 10-fold increase in the rate of postoperative day (POD) 1 discharges following robotic thoracoscopic anatomic resections over time. We aimed to determine factors associated with safe POD1 discharges.

Methods: We performed a retrospective analysis of a prospectively maintained database of robotic anatomic pulmonary resections between July 1, 2012, and June 30, 2022, with patients of the last 2.5 years forming the basis of this study. Data collected included demographics, insurance types, Area Deprivation Index (indicator of poverty), and operative and postoperative variables including length of stay, opioid use, daily pain levels, readmissions, and outpatient interventions. Factors associated with POD1 were analyzed using a logistic regression module.

Result: In total, 279 patients met inclusion criteria (91 POD1 discharges, 32.6%; none discharged with a pleural catheter). There was neither an increase of postdischarge interventions for pleural complications nor readmission in early discharge patients. After adjusting for relevant factors, younger age, right middle lobectomy, lower opioid use on POD1, operating room finish before 4 PM, and low Area Deprivation Index were significantly associated with POD1 discharge. A subanalysis of 49 patients, who could have been discharged on POD1, identified hypoxemia requiring home oxygen, atrial fibrillation, and poorly controlled pain being common mitigatable clinical factors delaying POD1 discharge.

Conclusions: Safe POD1 discharge following robotic thoracoscopic anatomic resection was achieved in 32% of cases. Identification of positive and negative factors affecting early discharge provides guidance for further modifications to increase the number of POD1 discharges. (JTCVS Open 2023;16:875-85)



Combination of robotic surgery and optimized ERATS protocol.

CENTRAL MESSAGE

Discharge home 1 day after elective robotic thoracoscopic anatomic lung resections is safe and not associated with increased postdischarge adverse events.

PERSPECTIVE

Minimally invasive robotic thoracoscopy together with effective postoperative pain management using opioid-sparing strategy within the context of enhanced recovery after thoracic surgery protocol creates optimal conditions for safe postoperative day 1 discharge following anatomic pulmonary resections.

See Discussion on Page 886.

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Abbreviations and Acronyms

ADI	= Area Deprivation Index
aOR	= adjusted odds ratio
CI	= confidence interval
ERATS	= enhanced recovery after thoracic surgery
LOS	= length of hospital stay
MME	= milligram morphine equivalent
POD	= postoperative day

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Many impactful innovations of thoracic surgery, especially the widespread use of minimally invasive thoracic surgery and patient-centered perioperative care protocols, have led to significant improvement of surgical outcomes of pulmonary resections. Successful implementation of enhanced recovery after thoracic surgery (ERATS) protocol is associated with effective pain control using opioid-sparing multimodality analgesic strategy, reduction of postoperative complications, shortened of length hospital of stay, and maximal patient comforts and satisfaction.[1-3] Recent studies have demonstrated an increasing incidence of safe early discharge to home, even on postoperative day 1 (POD1), after pulmonary anatomic resections, specifically after thoracoscopic surgeries.[4-9] Analysis of national databases such as the Society of Thoracic Surgeons General Thoracic Surgery database or the National Cancer database, showed an rate of 6% to 8% of POD1 discharges following anatomic lung resections in 2016 to 2018, with less than 5% of reporting institutions achieving POD1 discharge >20% of their cases and 30% of institutions not having any POD1 discharges.[4] In contrast, single-institution studies reported 53% to 63% of minimally invasive anatomic lung resections were discharged on POD1.[5,7] Although many clinical and demographic factors associated with POD1 discharges following pulmonary anatomic resections have been identified, the impact of socioeconomic status of patients on the ability to achieve POD1 discharges in this population remains to be investigated. Socioeconomic factors, either as individual, such as levels of education, average income, race, ethnicity, and locations of residence indicated by postal area code, or grouping together as a global indicator social-economic status, have been shown to influence surgical and medical outcomes of lung cancer therapy.[10]

Our group implemented ERATS in February 2018[11,12] and has continued to optimize our protocol to improve its performance to achieve high incidences of opioid-free and pain-free recovery after robotic thoracoscopic procedures.[13] Our current ERATS protocol is the optimized version that was implemented in January 1, 2020. We observed that up to 30% of our patients undergoing robotic anatomic resection and managed by the latest ERATS version were discharged home on POD1, representing a 17-fold and 6-fold increase, respectively, as compared with our pre- and initial ERATS phases (Figure 1). The goal of this study is to determine factors (demographics, clinicopathologic parameters [particularly in-hospital subjective pain levels and opioids use], as well as socioeconomic status using the well-validated Area Deprivation Index [ADI]) that are associated with safe POD1 discharge and to identify factors that can be mitigated to increase the incidence POD1 discharges.

METHODS

Patient Population

A retrospective analysis of data extracted from our prospectively maintained thoracic surgery database and the electronic medical record EPIC of patients at University of Miami Hospital was performed following institutional review board approval with a waiver of patient consent requirement (institutional review board number 20180827, October 31, 2018). Patients undergoing robotic thoracoscopic anatomic lung resections from July 1, 2012, to June 30, 2022, by 2 surgeons were reviewed. Patients in whom accurate assessment of postoperative pain and narcotic use was not feasible, such as remaining on endotracheal intubation/mechanical ventilation following lung resections, who had conversion to open thoracotomy, or had lung resections in combinations with other procedures such as chest wall resection, were excluded. In-hospital or 30-day postoperative mortality was reported but not included in the final analysis of this study. Patients were stratified to pre-ERATS subgroup (July 1, 2012, to January 31, 2018), initial ERATS subgroup (February 1, 2018, to December 31, 2019), the initial protocols as previously reported[11,14] and the optimized ERATS subgroup (January 1, 2020, to June 30, 2022: optimized protocol as described) (Table E1)[13] for analysis of the incidence of POD1 discharge. Patients of the optimized ERATS group form the basis of this study, as they have the greatest incidence of POD1 discharge. The implementation of our initial ERATS protocol and its subsequent modifications have previously been reported,[13,14] With effective opioid-sparing pain control and early ambulation observed in patients who receive ERATS, particularly following protocol optimization, expedited removal of bladder catheter (on morning rounds with urine output of 0.5-1 mL/kg/h overnight) and chest drain (in the morning of POD1 with no air leak on water seal and drainage of $\geq$ 0.5 mL/kg/h) on POD1 was instituted. We provided postdischarge prescriptions with the amount and the types of opioids (schedule II oxycodone and/or schedule IV tramadol) based on clinical assessment, predischarge briefing of patients regarding pain management and incisional versus neuropathic pain, and most particularly in-hospital pain levels and opioids requirements at the day of hospital discharge. Following successful removal of bladder catheter and pleural catheter on POD1, patients were immediately evaluated and counseled for discharge.

Data Source and Attributes

The thoracic surgery database prospectively collects detailed clinical parameters, including but not limiting to patient demographics, operative details, pathologic diagnoses, tumor–node– metastasis staging for primary lung cancer, 30-day postoperative complications (Clavien–Dindo classification), postoperative length of hospital stay (LOS), postdischarge

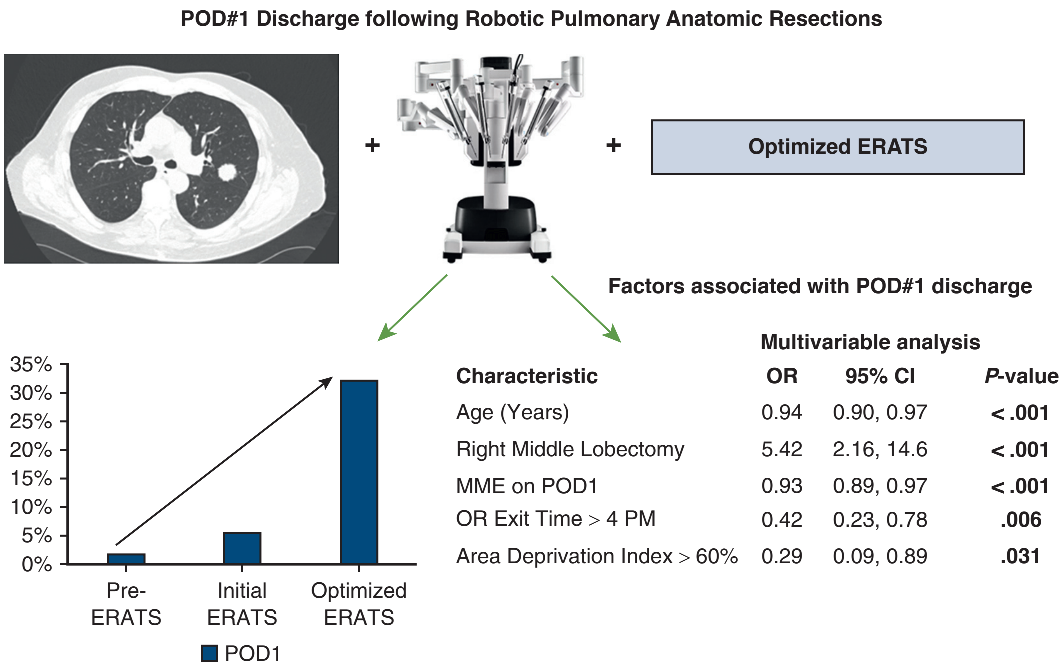

FIGURE 1. Combination of robotic surgery and optimized ERATS protocol leading to a stark increase in the percentage of POD1 discharged. Factors associated with early discharge on multivariate analysis such as resection type, narcotic use, early OR exit and socio-economic status as indicated by area of deprivation indexed are displayed. *POD*, Postoperative day; *ERATS*, enhanced recovery after thoracic surgery; *OR*, operating room.

interventions for pleural complications, and readmissions. Duration of bladder and pleural drains were recorded, as well reasons for not leaving on POD1 once all drains were removed.[15] In addition, the following measurements were extracted from hospital electronic medical records: daily pain scores (patient-reported pain levels were recorded using the visual analog pain numeric scores by nursing staff many times a day, as they frequently assessed pain levels to administer pro re nata analgesics as per ERATS protocol and daily pain scores were calculated as averages of multiple readings over a 24-hour period for up to fourth postoperative day) and in-hospital analgesics dispensed (schedule II opioids oxycodone, hydromorphone, morphine, fentanyl and schedule IV opioid tramadol; nonopioid analgesics: acetaminophen, gabapentin, and nonsteroidal anti-inflammatory drugs: ketorolac, ibuprofen, celecoxib). The quantities of opioids dispensed are expressed as per os morphine milligram equivalent (MME). Information regarding postdischarge readmissions, either to our hospital or to another health care facility, and postdischarge interventions for pleural complications, mainly symptomatic pleural effusion, were obtained from EPIC and via postdischarge telephone follow-ups and clinic visits. Postdischarge analgesics including types and dosage of opioids prescribed were collected from the discharge summary. The immediate filling and refilling (within 30-day after discharge) of all types of opioids were monitored by reviewing of EPIC and by routine surveying of our patients during telephone follow-ups by our advanced practice registered nurse and by the attending surgeons at postoperative clinic visits. Such independently obtained information were frequently cross-referenced the for accuracy using Florida's Prescription Drug Monitoring Program database.

Socioeconomic status ADI was obtained by querying the postal ZIP code. Data are collected by our nurse practitioners and research assistant. ADI is a metric of socioeconomic deprivation, and it is a composite of several neighborhood characteristics such as poverty, housing, employment, and education.[16,17] We used 5-digit ZIP codes to construct ADI to measure patients' neighborhood socioeconomic deprivation via linked ZIP codes. Greater indices indicate greater magnitudes of social deprivation and poverty. Previous works have demonstrated a positive association of high ADI with greater mortality among patients with head and neck, lung and prostate cancers.[10,18] The database is monthly audited for accuracy by one surgical faculty (D.M.N.). The study was conducted and reported in concordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[19]

Statistical Analysis

Demographics, operative/pathologic data, schedule II/IV opioid use, and clinical outcomes were summarized as frequencies for categorical variables and medians with an interquartile range for continuous variables after normality assessment. χ^2, Kruskal–Wallis, and Mann–Whitney *U* tests were used to compare groups where appropriate. To determine factors associated with POD1, candidate variables were selected based on clinical relevance and literature review. Univariable logistic regression models assessed each variable of interest individually, and an adjusted model was constructed after variable imputation of missing variables (by mode/mean) and multicollinearity assessment (with the variance inflation factor).

The analysis was performed using R (4.2.2 [2022-10-31 ucrt], R Foundation for Statistical Computing) with multiple packages, including 'gtsummary,' 'imputeMissings,' 'sociome,' and 'cutpointr.'

RESULTS

Analysis of 730 eligible patients between January 7, 2012, and June 30, 2022, stratified to pre-ERATS, initial ERATS, and optimized ERATS cohorts indicated a drastic increase of the incidence of POD1 discharges in the optimized ERATS cohort (Figure 2). Although these patient cohorts have comparable demographic and pathologic features (Table 1), the optimized ERATS group had

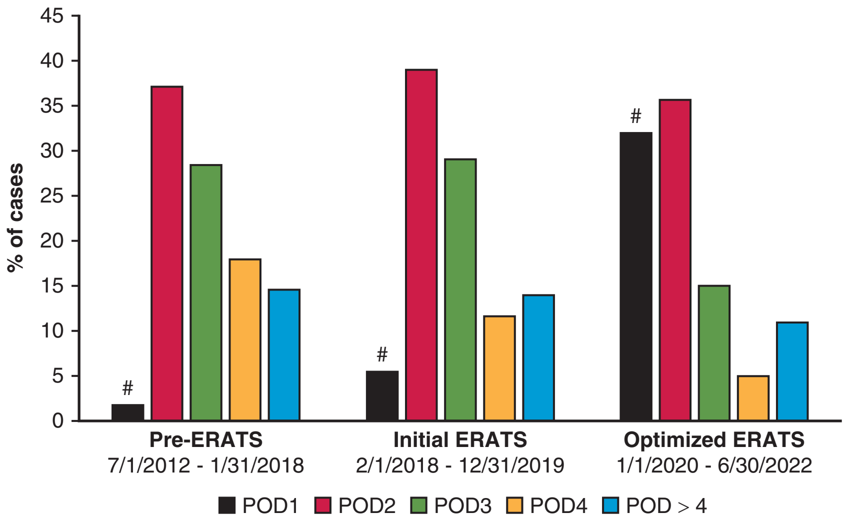

FIGURE 2. Comparative analysis of postoperative hospital length of stay (*LOS*) of consecutive patients undergoing elective same-day admit robotic pulmonary anatomic resections before (*Pre-ERATS*) and following implementations of ERATS care pathways (initial protocol and optimized protocol as described in the Methods section). Optimized ERATS cohort has the greatest incidence of POD1 discharges, $P < .00001$ versus the other 2 cohorts. *POD*, Postoperative day; *ERATS*, enhanced recovery after thoracic surgery.

significantly shorter overall hospital LOS, greater incidence of segmentectomy, and lowest incidence of complications, particularly those of Dindo–Clavien classes 1 to 2. Available data on postoperative daily pain, average in-hospital opioid use, and postdischarge opioid consumption of each subgroup indicated that ERATS implementation was associated with a significant reduction of both postoperative acute pain and in-hospital opioid consumption, most profound in the optimized ERATS cohort.

The following analysis focuses on elucidating clinicopathologic factors and social-economic status collectively represented by ADI associated with POD1 discharges in the optimized ERATS patients. A total of 91 patients (32.6%) were discharged on POD1 (POD1 discharge group). All were discharged directly home, and none had any indwelling catheters. Baseline characteristics of the POD1 and POD >1 discharges of this cohort are shown in Table 2. Patients discharged 1 day after lung resections were younger, more frequently female, had better forced expiratory volume in 1 second (% normal), had right middle lobectomy, reported significantly less pain, needed fewer opioids on POD1, and tended to have commercial insurance ($P = .08$). Patients of this group experienced much lower postoperative complications, all of which were postdischarge symptomatic pleural effusion requiring thoracentesis. There was only 1 readmission, for thoracentesis. There was no difference regarding pleural interventions between the 2 groups but significantly more readmissions for diverse indications were noted in the POD >1 group (Table E2). Further granular analysis of 49 patients of the POD >1 discharge (36 discharged on POD2, 12 discharged on POD3, and 1 discharged on POD5) who had all drains removed on POD1 and could have been discharged but remained hospitalized indicated in 63.2% of patients (31 patients), inadequate pain control, atrial fibrillation, hypoxemia requiring home oxygen supplementation, nausea–vomiting, and low urine output after removal of bladder catheter were the most frequent reasons for keeping patients hospitalized (Figure 3). No identifiable medical indications for keeping patient extra days after POD1 was noted in 12 patients (24.5%). Most of these patients declined early discharges citing inadequate family support and thus reasons for delayed discharges were classified as patient-related social factors. Six other patients (12.2%) stayed an extra day due to miscellaneous medical reasons (for instance, dysphonia requiring investigation, fatigue due to baseline anemia, confusion due to baseline mild dementia).

Univariable and multivariable logistic regression analyses to identify factors associated with POD1 are shown in Table 3. The unadjusted effect of female sex and right middle lobectomy appeared to be associated with increased successful POD1 discharges. In contrast, older age, greater total MME on POD1, increased pain level on POD1, governmental insurance (Medicare/Medicaid), and leaving the operating room after 4 PM were associated with decreased POD1 discharge achievement. Race (White vs non-White) and ADI didn't appear to be statistically significant. The significant effects of female sex and governmental insurance were removed after adjusting for age, whereas adjusting for race made ADI significant. No significant interactions between female and age, governmental insurance and age, or ADI and race were found. In the final adjusted model, only 5 factors were

TABLE 1. Comparative analysis of robotic anatomic resections over a 10-year period stratified to subgroups based on implementation of enhanced recovery protocols

	Pre-ERATS July 1, 2012, to January 31, 2018	Initial ERATS February 1, 2018, to December 31, 2019	Optimized ERATS January 1, 2020, to June 30, 2022	*P* value
n	267	181	279	
F:M	154:113	105:76	163:116	.98
Age, y	68 [60-74]	69 [62-75]	69 [62-75]	.56
LOS, d	3.0 [2.0-4.0]	3.0 [2.0-3.5]	2.0 [1.0-3.0]	**<.00001***
POD1	1.87%	5.50%	32.60%	**<.00001†**
Anatomic, n (%)				
Lobar and higher	229 (85.7%)	141 (77.9%)	204 (73.1%)	
Sublobar	38 (14.3%)	40 (22.1%)	75 (26.9%)	**.00072‡**
Pathology				
Benign	5	4	9	
Neoplasms	263 (98.1%)	178 (97.8%)	271 (96.8%)	.57
Secondary/others	15	14	15	
Primary	248 (94.3%)	164 (92.1%)	256 (94.4%)	
Stage 0-1	187 (75.4%)	128 (78.1%)	188 (71.0%)	.53
Stage 2-3	61 (24.6%)	36 (21.9%)	67 (29.0%)	
Complications (C-D)				
0	198 (74.1%)	143 (79.0%)	237 (84.9%)	**.0075§**
1-2	49 (18.3%)	24 (13.2%)	22 (7.9%)	
3-4	20 (7.5%)	14 (7.8%)	20 (7.2%)	
5	1 (postdischarge mortality) (0.4%)	1 (in-hospital mortality) (0.5%)	1 (in-hospital mortality) (0.3%)	
Pain level				
POD0	7.1 [6.1-7.5]	4.8 [3.8-6.2]	4.5 [3.0-5.5]	**<.00001‖**
POD1	5.5 [4.1-6.5]	3.3 [2.1-5.1]	2.0 [1.1-3.5]	**<.00001¶**
POD2	4.1 [3.2-5.6]	2.5 [1.2-4.2]	1.3 [0.0-3.0]	**<.00001¶**
In-hospital total MME	68.7 [40.1-109.0]	47.0 [31.5-83.5]	21.0 [7.6-39.4]	**<.00001¶**
In-hospital average MME	24.7 [15.2-41.5]	20.0 [15.1-27.0]	10.5 [4.1-19.9]	**<.00001#**

P values in bold indicates statistically significant ≤.05. *ERATS*, Enhanced recovery after thoracic surgery; *F*, female; *M*, male; *LOS*, length of stay; *POD*, postoperative day; *MME*, milligram morphine equivalent. **P* <.00001 optimized ERATS versus pre-ERATS and initial ERATS; *P* = .18 pre-ERATS versus initial ERATS. †χ^2, pairwise analysis. ‡χ^2, *P* = .01 pre-ERATS versus initial ERATS; *P* = .00026 pre-ERATS versus optimized ERATS; *P* = .25 initial ERATS versus optimized ERATS. §*P* = .11 pre-ERATS versus initial ERATS; *P* = .0017 pre-ERATS versus optimized ERATS; *P* = .10 initial ERATS versus optimized ERATS. ‖Kruskal–Wallis for group and Mann–Whitney *U* test for pair-wise comparison. ¶Pairwise analysis. #*P* = .08 Pre-ERATS versus initial ERATS: *P* < .00001; pre-ERATS and initial ERATS versus optimized ERATS by pairwise analysis.

significantly associated with POD1 discharge, including younger age, right middle lobectomy, lower opioid use on POD1, leaving the operating room before 4 PM, and lower ADI score (greater socioeconomic status). Right middle lobectomy was associated with more than a 5-fold increase of POD1 discharge achievement (adjusted odds ratio [aOR], 5.48; confidence interval [CI], 2.16-14.6, *P* < .001), whereas having high ADI was associated with 71% decreased POD1 discharge (aOR, 0.29; CI, 0.09-0.08, *P* = .031), leaving OR after 4 PM was associated with 58% decreased POD1 discharge (aOR, 0.42; CI, 0.23-0.78, *P* = .006), a 1-year increase in age was associated with decreased POD1 discharge by 6% (aOR, 0.94; CI, 0.90-0.97, *P* < .001), and a 1-unit increase of total MME was associated with decreased POD1 discharge by 7% (aOR, 0.93; CI, 0.89-0.97, *P* < .001).

DISCUSSION

Our retrospective study demonstrated that POD1 discharge after robotic anatomic lung resection is safe and feasible in high percentages of patients, not associated with increased incidence of postdischarge intervention for pleural complications, and associated with much lower incidence of readmission compared with the POD >1 cohort. Understanding factors associated with POD1 discharges and identifying mitigatable medical conditions that prevent such practice would enable development of strategy to facilitate POD1 discharges.

Our study represents a longitudinal review of clinical outcomes of robotic pulmonary anatomic resections by 2 surgeons completely committed to ERATS care protocol at a single academic institution. Even though POD1 discharge is not a stated objective of ERATS, salutary

TABLE 2. Comparative analysis of POD1 versus POD >1 discharges

	POD1 (n = 91)	POD >1 (n = 188)	
Age, y	64.0 [56.5-71.7]	71.0 [63.0-77.0]	**.00001**
Sex (F/M), n (%)	63/28 (69.2/30.7)	100/88 (53.2/46.8)	**.013**
Race (White/non-White), n (%)	78/13 (85.7/14.3)	164/24 (87.2/12.8)	.71
FEV1 (% normal)	92.5 [81.7-103.0]	88.0 [76.0-99.0]	**.0466**
DLCO (% normal)	78.5 [71.0-88.0]	77.0 [63.2-87.0]	.111
BMI, kg/m^2	27.4 [24.6-230.0]	27.25 [23.4-31.3]	.88
Operating time, min	158.5 [137.0-211.0]	177.5 [141.7-210.5]	.11
EBL, mL	50 [20-80]	80 [50-100]	**.00001**
Left/right, %	38.4/61.5	41.5/58.5	
Upper lobe	42.5	53.2	.12
Middle lobe	20.2	5.6	**.0002**
Lower lobe	35.5	40	
Lobectomy, %	69.2	76	.24
Pain level POD1	1.7 [0.6-3.1]	2.3 [1.3-3.7]	**.0083**
MME POD1	5.0 [0.0-15.0]	10.0 [0.0-21.2]	**.00062**
30-d complications (C-D), n (%)			
0	87 (95.6%)	150 (79.8%)	**.00053**
1-2	0	22 (11.7%)	**.0001**
3-4	4 (4.4%)	16 (8.5%)	.32
Readmission, n (%)	1 (1.1%)	13 (6.9%)	**.0001**
Outpatient thoracentesis	3 (3.3%)	6 (3.9%)	1.00
Pathology			
Benign: malignant	1/90	8/180	.279
Lung neoplasms			
Secondary/others	5	11	
Primary	86	169	1.00
Stage 0-1, n (%)	73 (84.9)	128 (75.7)	.1000
Stage 2-3	13 (15.1)	41 (24.3)	
Insurance (government/commercial), n (%)	32.9/67.1	46.3/53.7	.082
Surgeon			.057
Surgeon 1	60 (29%)	147 (71%)	
Surgeon 2	30 (41%)	43 (59%)	
ADI 60%	80 (31%)	181 (69%)	**.048**
OR exit time (4 PM)	27 (23%)	91 (77%)	**.005**

P values in bold indicates statistically significant ≤.05. *POD*, Postoperative day; *F*, female; *M*, male; *FEV1*, forced expiratory volume in 1 second; *DLCO*, diffusing capacity of the lungs for carbon monoxide; *BMI*, body mass index; *EBL*, estimated blood loss; *MME*, milligram morphine equivalent; *ADI*, Area Deprivation Index; *OR*, operating room.

postoperative outcomes achieved by effective enhanced recovery protocol, most importantly effective opioid-sparing pain control, lower postoperative complications allowing shorter LOS, are inducive to more accelerated discharges. It is not surprising to see the association between optimized ERATS and the high incidence of POD1 discharges. Our own experience is completely in line with data reported in the literature: 2% in 2012 to 2017, 5% in 2018 to 2020, and 30% at the present time, also coinciding with our ongoing optimization of ERATS at our institution. We frequently discharge robotic pulmonary wedge resections and mediastinal tumor resections on POD1 (in fact as previously reported, the median LOS of these patients was 1 day[13] and more recently many were POD0 discharges). Recognizing POD1 discharge is safe in these patients, we extended our expedite discharge practice to anatomic lung resection population. This comes with ongoing modification of postoperative care: expedite drain removal, better opioid-sparing pain control, preoperative counseling to setup realistic postoperative expectations and home care arrangements as well as a robust postdischarge follow-up regular phone calls by our

140 patients were evaluated for POD1 discharge once chest tube and bladder catheters were removed:

- 91 were discharged to home
- 49 could not

Factors preventing possible POD1 discharges of these 49 patients

Social factors: 12	24.50%
CVS (atrial fibrillation): 6	12.20%
Pain: 13	26.50%
Hypoxemia requiring home oxygen: 6	12.20%
GI (nausea-vomiting): 3	6.10%
GU (oliguria following catheter removal) 3	6.10%
Others: 6	12.20%

Reluctance to be discharged because of no family support

31 patients with clinical factors that could be mitigated to increase POD1 discharges

36 of these 49 patients were subsequently discharged on POD2, all to home

51 of 68 patients (75%) having chest tubes removed on POD2 were discharged home on the same day; all had small air leak necessitating keeping of chest tube beyond POD1

FIGURE 3. Granular analysis of patients eligible for discharge on POD1 (removal of pleural and bladder catheters) who elected to remain in patient. *POD*, Postoperative day; *CVS*, cardiovascular system; *GI*, gastrointestinal; *GU*, genitourinary.

advanced practice registered nurse to monitor progress and to instill confidence in patients of their recovery. The results of our study are in keeping with recent reports of safe POD1 discharges following anatomic lung resections,[4-9] especially with minimally invasive thoracoscopy and in high-volume medical centers.[8] Our study is the first, to our knowledge, to explore the impact of social-economic factors collectively represented by ADI on POD1 discharges in this patient population. Economic deprivation severely and adversely (odds ratio, 0.29; 95% CI, 0.09-0.89) affects the ability to be discharged home on POD1. This observation offers a unique opportunity for further research on interactions of socioeconomic disadvantages and surgical care as well as potential development of care strategies/interventions to improve POD1 discharges and other outcome metrics in general.

Our study also allowed us to identify factors that can be mitigated to facilitate POD1 discharge. We have instituted strategies to address these factors: Rapid assessment of pain level for real-time adjustment of analgesics, aggressive atrial fibrillation prophylaxis with increasing doses of β-blocker to keep baseline cardiac rhythm less than 80/min whenever possible,[20] identifying patients who might need home oxygen early in the preoperative evaluation phase of care and ordering home oxygen equipment immediately after the procedure, maintaining urine output of 0.8 to 1.0 mL/kg/h overnight following the index operation to allow successful bladder catheter

TABLE 3. Univariable (left pane: unadjusted) and multivariable (right panel: adjusted) models for factors associated with POD1 discharge

Characteristic	Univariable module			Multivariable module		
	OR	95% CI	*P* value	OR	95% CI	*P* value
Age, y	0.94	0.92-0.97	**<.001**	0.94	0.90-0.97	**<.001**
Sex (female)	1.73	1.03-2.94	**.041**	1.68	0.91-3.17	.10
Race (White)	0.90	0.44-1.90	.8	0.80	0.35-1.90	.6
Insurance (Medicare/Medicaid)	0.55	0.32-0.93	**.026**	0.79	0.40-1.53	.5
Surgeon	1.71	0.98-2.97	.058	1.56	0.80-3.02	.2
Right middle lobectomy	4.65	2.15-10.5	**<.001**	5.42	2.16-14.6	**<.001**
Pain on POD1	0.83	0.70-0.96	**.017**	0.91	0.75-1.10	.4
MME on POD1	0.94	0.91-0.97	**<.001**	0.93	0.89-0.97	**<.001**
Operating room exit time >4 PM	0.47	0.27-0.79	**.005**	0.42	0.23-0.78	**.006**
ADI >60%	0.40	0.15-1.02	.054	0.29	0.09-0.89	**.031**

P values in bold indicates statistically significant ≤.05. ADI >60% denotes poverty. *POD*, Postoperative day; *CI*, confidence interval; *OR*, odds ratio *MME*, milligram morphine equivalent; *ADI*, Area Deprivation Index.

removal at 5:00 AM on POD1, and maintaining intravenous fluid until first void. Further analysis of patients discharged home on POD2, 75% of them were discharged soon after removal of the chest tubes that were kept for small air leak. Recent study by Greer and colleagues[5] from Tennessee reported up to 65% of POD1 discharge after they instituted intraoperative strategy to minimize or even eliminate postoperative air leak. Geraci and colleagues[7] from New York University reported a 53% incidence of safe POD1 discharged after anatomic robotic lung resections; they, however, did send some patients home on POD1 with pleural catheters in place. Addressing postoperative air leak and other factors identified in this study would potentially allow us to achieve 50% or more POD1 discharge in our population. Additional analysis of 115 patients undergoing robotic anatomic resection between July 1, 2022, and March 31, 2023, indicated 39% POD1 discharges without intervention for pleural complications nor readmissions. Fast turnover of hospital beds facilitate timely surgical care of patients with lung cancer. Patient report outcomes and cost analysis of robotic pulmonary anatomic resections with particular attention to POD1 population are topics of our future studies.

We observed an association with a 71% decrease in POD1 discharges in patients of lower socioeconomic status. Although initially not statistically significant after adjusting for the impact of race, we are able to observe the true effect of socioeconomic disadvantage on early discharge on POD1 after anatomic resection. Our findings are concordant with previous work suggesting impact of ADI on lung cancer prevalence and mortality.[21] Our work highlights the importance of adjusting for race in using socioeconomic metrics, especially in relatively small cohorts. Future more highly powered studies are necessary to further stratify the impact of race on postoperative outcome, especially in a socioeconomic disadvantaged, in an optimized enhanced recovery protocol.

Our study has many limitations inherent to a single-center retrospective analysis. Namely inherent selection bias and being representative of a limited number of surgeons with a relatively standardized practice pattern. Furthermore, our service population skews relatively older possibly impacting pain levels and opioid usage. The strengths include a very granular dataset with robust auditing and close follow up with our mid-level providers. Due to our ability to analyze ongoing optimizations, we were ablet to observe the longitudinal impact of ERATS optimization on early and safe discharges.

In summary, our longitudinal study identifies a significant increase in POD1 discharge of our contemporary robotic anatomic pulmonary resections, coinciding with the implementation of our optimized ERATS protocol. We further demonstrated that POD1 of this patient cohort is safe and associated with very low risks of postdischarge complications and readmission (Figure 1). Univariate and multivariate analysis identify factors associated with safe POD1 discharge, especially the adverse effect of high ADI, allowing the development of a strategy to facilitate early discharges in patients with disadvantaged socioeconomic status.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/postoperative-day-1-discharge-following-robotic-thoracoscopic-pulmonary-anatomic-resections-in-the-era-of-enhanced-recovery-protocol-a-single-institution-experience.

Conflict of Interest Statement

The authors reported no conflicts of interest. The authors discuss the off-label use of liposomal bupivacaine (EXPAREL; Pacira Pharmaceuticals Inc) for intercostal nerve block, used with institutional approval.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: enhanced recovery after surgery protocol, robotic thoracic surgery, opioid, liposomal bupivacaine, intercostal nerve block, anatomic pulmonary resection, postoperative pain, postoperative opioid utilization, early discharge after lung resection

TABLE E1. Components of optimized ERATS protocol at the University of Miami

Preoperative consultation
Extensive counseling of patients and family members about operative plans
Realistic expectation of postoperative recovery and multimodal pain management, manifestation of neuropathic pain and its management
Printed information booklet with instructions
Preoperative clinic visit
Complete review of medical and anesthesia history
Preoperative clearance
Routine preoperative instructions
Perioperative care
Acetaminophen: 1000 mg (1 h before surgery)
Gabapentin: 100 mg (1 h before surgery)
Prophylactic antibiotics (cefazolin 2 g for <120 kg or 3 g >120 kg; vancomycin 1000 mg for penicillin allergy)
Anesthesia care: Patient-directed fluid management, prophylaxis for postoperative nausea–vomiting (PONV)
Intercostal nerve blocks and infiltration of surgical wounds with local anesthetics (30 mL of 0.25% bupivacaine admixed with 20 mL of liposomal bupivacaine); 30 mL is used for subpleural infiltration of 2nd-10th intercostal spaces.
Postoperative care
Analgesics
Acetaminophen 1000 mg PO Q8 hrs
Tramadol 50 mg PO Q6 hrs PRN (pain scale <4)
Ibuprofen 600 mg PO Q8 hrs postoperatively or Toradol 15 mg Q6 hrs IV PRN for 2 d (if no medical contraindications); replaced by celecoxib 200 mg Q12 hrs starting February 1, 2022; timing of first dose is at the discretion of the attending surgeon
Gabapentin 100 mg PO Q8 hrs; titrating greater doses based on tolerance to achieve control of neuropathic pain
Oxycodone 5 mg PO Q6 hrs PRN (pain scale: 4-6)
Oxycodone 10 mg PO Q6 hrs PRN (pain scale: 7-10)
Morphine 2 to 4 mg IV Q6 hrs PRN or hydromorphone 0.5-1.0 mg IV or 2-4 mg PO Q6 hrs PRN for breakthrough pain
Heparin 5000 U subcutaneous Q8 h
Metoprolol 12.5 mg Q12 hrs (if not already on a beta-blocker following anatomic resection)
Tamsulosin 0.4 mg QD (>50 years old)
Bowel regimen (Colace and Dulcolax scheduled; MiraLAX and milk of magnesia PRN)
Incentive spirometer and ambulation on POD 0
Regular diet as tolerated staring POD 0; ice cream to rule out chylothorax on POD0
Assessment for home oxygen requirement (to prevent discharge delays) by checking for oxygen saturation ≤90% on room air with ambulation
Chest tube removal (no air leak off −20 cm suction on POD 1, drainage is not sanguineous, 0.1-0.3 mL/kg/h for 6 hrs on day of tube removal)
Foley catheter removal (POD 1)
Intravenous fluid 1 mL/kg until first voiding following removal of Foley catheter
Frequent pain assessment by nursing staff and APRN and appropriate administration of scheduled and PRN analgesics based on pain level; documentations of pain levels Q4 hrs to Q6 hrs using then visual analog pain scale.
Discharge plan
Verbal and printed discharge instructions regarding prescriptions, pain management especially signs and symptoms and therapy for neurogenic pain
APRN telephone follow-up POD3 and POD7
Contact ARNP or physician's office for advice and management of excessive neuropathic pain
Postdischarge analgesics
Acetaminophen 1000 mg PO Q8 hrs for 20 d
Tramadol 50 mg PO Q6 hrs for 3 d (12 tablets; if used postoperatively in-hospital)
Gabapentin 100 mg PO Q8 hrs for 60 d (30 d supply refill ×1); titrated up to address neurogenic pain
Ibuprofen 600 mg PO Q8 hrs for 20 d
Oxycodone 5 mg PO Q6 hrs PRN for 3 d (12 tablets; if used postoperatively in-hospital)
Pantoprazole 40 mg PO daily for 20 d
Lidocaine patch 4% applied to affected area twice daily PRN

Our optimized ERATS protocol details are provided in the table. *ERATS*, Enhanced recovery after thoracic surgery; *PO*, per os; *Q*, every; *hr*, hours; *PRN*, pro re nata; *POD*, postoperative day; *APRN*, advanced practice registered nurse.

TABLE E2. Complications list and frequency by ERATS era

Complications (C-D)	Pre-ERATS	Initial ERATS	Optimized ERATS	*P*
Total	267	181	279	
0	198 (74.1%)	143 (79.0%)	237 (84.9%)	**.0075**
1-2	49 (18.3%)	24 (13.2%)	22 (7.9%)	
Cardiovascular	20	3	6	
Atrial fibrillation	20 (10.1%)	3 (2.1%)	6 (2.5%)	**.000298***,†
Respiratory	13	15	14	
Air leak >5 d	5	6	9	
Pleural effusion/chylothorax (conservative therapy)	0	3	4	
Pneumonia/atelectasis	2	0	1	
Pneumothorax/subcutaneous emphysema (no intervention)	6	6		
Renal	12	5	1	
Urinary retention	12 (6.1%)	5 (3.5%)	0 (0.0%)	**.003166**‡,§
Acute renal failure	0	0	1	
Others	4	1	1	
Ileus	2	0	0	
Anxiety	1	0	0	
Exacerbation Guillain-Barré	1	0	0	
Wound cellulitis	0	1	1	
3-4	20 (7.5%)	14 (7.8%)	20 (7.2%)	
Cardiovascular	1	1	2	
Acute coronary syndrome	0	1	2	
Atrial fibrillation/other arrhythmia requiring ICU admission	0	0	0	
Respiratory	17	11	16	
Pleura effusion/empyema requiring intervention	10 (5.0%)	7 (4.9%)	13 (5.4%)	
Chylothorax intervention/reoperation	0	1	3	
ICU admission (pulmonary embolism, respiratory failure)	7	3	0	
Renal	1	0	1	
Urinary retention	0	0	0	
Acute renal failure	1	0	1	
Bleeding requiring reoperation	1	2	1	

P values in bold indicates statistically significant ≤.05. Detailed are our most frequent complications during the three periods of our study. *ERATS*, Enhanced recovery after thoracic surgery; *ICU*, intensive care unit. *Initial ERATS and optimized ERATS versus pre-ERATS: *P* = .003 and .001. †Initial ERATS versus optimized ERATS: *P* = .778. ‡Optimized ERATS versus pre-ERATS: *P* = .00056. §Optimized ERATS versus initial ERATS: *P* = .019.