Achieving opioid-free discharge following robotic thoracic surgery: A single-institution experience

Daniel J. Gross, MD, Ahmed Alnajar, MD, Nestor R. Villamizar, MD, and Dao M. Nguyen, MD, MSc, FRCSC, FACS

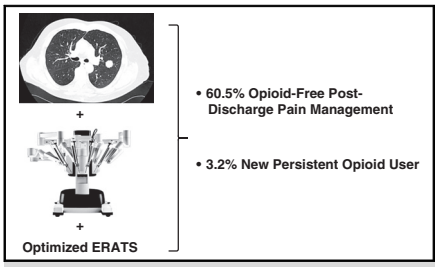
ABSTRACT

Objectives: Enhanced recovery after thoracic surgery (ERATS) protocols use a combination of analgesics for pain control and have been associated with decreased opioid requirements. We investigated the impact of continual ERATS refinement on the incidence of opioid-free discharge.

Methods: We retrospectively analyzed our prospectively maintained institutional database for elective, opioid-naive robotic thoracoscopic procedures. Demographics, operative outcomes, postoperative opioid dispensed (morphine milligram equivalent), and opioid discharge status were collected. Our primary outcome of interest was factors associated with opioid-free discharge; our secondary objective was to determine the incidence of new persistent opioid users.

Results: In total, 466 patients from our optimized ERATS protocol were included; 309 (66%) were discharged without opioids. However, 34 (11%) of patients discharged without opioids required a prescription postdischarge. Conversely, 7 of 157 patients (11%), never filled their opioid prescriptions given at discharge. Factors associated with opioid-free discharges were nonanatomic resections, mediastinal procedures, minimal pain, and lack of opioid usage on the day of discharge. More importantly, 3.2% of opioid-free discharge patients became new persistent opioid users versus 10.8% of patients filling opioid prescriptions after discharges ($P = .0013$). Finally, only 2.3% of opioid-naive patients of the entire cohort became chronic opioid users; there was no difference in the incidence of chronic use by opioid discharge status.

Conclusions: Optimized opioid-sparing ERATS protocols are highly effective in reducing opioid prescription on the day of discharge. We observed a very low rate of new persistent or chronic opioid use in our cohort, further highlighting the role ERATS protocols in combating the opioid epidemic. (JTCVS Open 2023;15:508-19)



Optimized ERATS increases opioid-free discharges and decrease persistent opioid use.

CENTRAL MESSAGE

Minimizing postoperative pain and opioid use by enhanced recovery protocol is associated with high incidence of opioid-free discharges and low incidence of persistent opioid users.

PERSPECTIVE

Achieving opioid-free postdischarge after robotic thoracic surgery minimizes opioid availability of addiction-prone schedule II narcotics to the public and thus directly contributes to the fight against the opioid epidemic.

The overarching goal of implementing the enhanced recovery after thoracic surgery (ERATS) protocol is to achieve predictable and optimal postoperative outcomes: effective pain control using opioid-sparing multimodality analgesic strategy, lowest-possible postoperative complications, short length of stay (LOS) in the hospital, maximal patient comfort and satisfaction, as well as optimal cost-effectiveness.[1,2] Significant postoperative pain is intrinsic to all thoracic surgical procedures, regardless of the surgical approaches, either by open thoracotomy or by minimally invasive thoracoscopic techniques, with the difference being only in the magnitude and duration of somatic as well as neuropathic pain. Before ERATS, schedule II oral/intravenous opioids and/or thoracic epidural analgesia using mixtures of local anesthetic and opioids were frequently used for acute postoperative pain, with high incidence of side effects reported. Although every component of the enhanced recovery protocol is important, and they all work synergistically to yield the most optimal outcomes, effective pain control following thoracic surgery is the cornerstone of ERATS. Local infiltration of the intermediate-acting local anesthetic agent bupivacaine and/or long-acting local anesthetic formulation liposomal bupivacaine (EXPAREL; Pacira Pharmaceuticals, Inc) to skin incision sites and to the

From the Division of Thoracic Surgery, The DeWitt Daughtry Department of Surgery, The University of Miami, Miami, Fla.

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Address for reprints: Dao M. Nguyen, MD, MSc, FRCSC, FACS, University of Miami, 1295 NW 14th St, Suite J, Miami, FL 33136 (E-mail: DNguyen4@med.miami.edu).

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Abbreviations and Acronyms
ERATS = enhanced recovery after thoracic surgery
LOS = length of stay
MME = milligram morphine equivalent
PDMP = Prescription Drug Monitoring Program

intercostal subpleural spaces for intercostal nerve blocks together with scheduled dosing of nonopioid analgesics such as acetaminophen, nonsteroidal anti-inflammatory drugs, and gabapentin is a preferred pain-management strategy. Following ERATS implementation, our group and others have reported a significant decrease of postoperative pain levels as well as in-hospital and postdischarge opioid requirement after thoracotomy or robotic thoracoscopy procedures.[3-6] Patient-reported subjective pain levels using the visual analog scale for pain score and opioid needs as shown by the milligram of morphine equivalent (MME) of opioid consumption are frequently used metrics to indicate successful ERATS. Since its implementation in February 2018, our ERATS has been subsequently optimized to a nearly opioid-free protocol.[7] We achieved a drastic reduction of in-hospital and postdischarge opioid (particularly the schedule II) use, with 60% of patients discharged without any opioid prescription and only a 10% incidence of schedule II narcotics use following elective robotic thoracoscopic procedures.[7] The primary objective of this retrospective, single-institution study is to identify factors associated with opioid-free discharge after robotic thoracoscopic procedures in opioid-naïve patients. The secondary objective is to determine the effect of opioid-free discharges on intermediate- and long-term opioid use, particularly the emergence of new persistent opioid users.

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, renewed November 1, 2022). Patients undergoing robotic thoracic surgical procedures from January 1, 2020, to December 31, 2021, were reviewed. All adult patients (>18 years old) undergoing elective robotic video-assisted thoracoscopy for pulmonary resections (nonanatomic wedge resections, anatomic resections: segmentectomy, lobectomy, bilobectomy with intrathoracic lymphadenectomy for pulmonary malignancy) or mediastinal–pleural procedures (for instance, thymectomy, resection of thymoma/thymic lesions or posterior mediastinal tumors/cysts, pleurectomy for pneumothorax) in whom safe and complete access to the posterior intercostal spaces for intercostal nerve block could be achieved and who were opioid-naïve were included. Based on the surgical procedures, patients were stratified into an anatomic lung resection (segmentectomy, lobectomy, bilobectomy) subgroup and a wedge lung resection/mediastinal–pleural procedures subgroup to minimize heterogeneity inherent to patient populations undergoing these surgical procedures, such as demographics, surgical indications, operating time, hospital LOS, postoperative complications, and in-hospital narcotic needs. Patients in whom an accurate assessment of postoperative pain and narcotic use was not feasible, such as those remaining on endotracheal intubation/mechanical ventilation following robotic video-assisted thoracoscopy or who had conversion to open thoracotomy, were excluded. The study was conducted and reported in concordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[8] The implementation of our initial ERATS protocol and its subsequent modifications have previously been reported[7,9] (Table E1). We provided postdischarge instructions and 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, in-hospital pain levels, and opioid requirements at the day of hospital discharge (Table E2).

Data Source and Attributes

The thoracic surgery database prospectively collects detailed clinical parameters, including but not limiting to patient demographics, operative details, pathologic diagnoses, TNM staging for primary lung cancer, 90-day postoperative complications (Clavien–Dindo classification), LOS, and readmission.[10] 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 analgesics as needed 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 the nonsteroidal anti-inflammatory drugs ketorolac and ibuprofen). The quantities of opioids dispensed are expressed as MME taken orally. Information regarding postdischarge readmissions, either to our hospital or to another health care facility, 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 days after discharge) of all types of opioids was 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 was frequently cross-referenced for accuracy using the Florida's Prescription Drug Monitoring Program (PDMP) database. Opioid use at intervals following discharges (31-90, 91-180, and 181-365 days) were queried using the PDMP, and the indications of opioid use were verified using electronic medical records and/or queries of patients. Opioid use for defined indications nonattributable to the indexed operations (for instance, other surgical procedures, symptomatic coughs requiring codeine, chronic back pain, acute abdominal pain) was excluded from analysis. New persistent opioid use was defined as an opioid-naïve patient who filled an opioid prescription attributed to the index operation and filled at least 1 additional opioid prescription between 91 and 180 days after surgery.[11,12] Chronic postoperative opioid use was defined as filling at least a 120-day supply within 1 year after surgery (adapted from the definition of chronic opioid users by Lee and colleagues[12]). Data were collected by our nurse practitioners and research assistant. The database is monthly audited for accuracy by one surgical faculty (D.M.N.).

Statistical Analysis

Demographics, operative/pathologic data, schedule II/IV opioid use, and clinical outcomes were summarized using descriptive statistics (frequencies [percentages] and medians [interquartile ranges, quartile 1-quartile 3]) and compared using the Pearson χ^2 test or Fisher exact test for categorical variables, and Wilcoxon rank sum test for continuous

variables where appropriate. Uni- and multivariable logistic regression models were used to analyze factors associated with MME0 for the entire patient cohort. Subgroup analyses for wedge/mediastinal and anatomical resection procedures were performed. Statistical analysis was performed with R software (version 4.2.1; R Foundation for Statistical Computing).

RESULTS

A total of 466 patients met the inclusion criteria (211 anatomic lung resections, 255 wedge resections/mediastinal–pleural procedures) (Consolidated Standards of Reporting Trials diagram, Figure 1). Collectively, 309 patients were discharged without opioid prescriptions, whereas 157 patients received prescriptions for either tramadol and/or oxycodone for up to 3 days as per guidelines of the state of Florida's PDMP. Careful outpatient follow-up cross-referenced with the state's PDMP database indicated only 275 of 309 patients remained opioid-free and 34 patients (11%) required opioid, mainly tramadol, prescriptions within 30 days of discharge. Conversely, of 157 patients with opioid prescription on the day of hospital discharge, 7 (11%) never filled the prescription. Overall, 282 patients (60.5%) of the entire cohort never required opioids after discharge from hospital (MME0 group) whereas 184 (39.5%) needed outpatient opioids, and they constitute the MME+ cohort. Further analysis of contributing factors to MME0/MME+ was performed on subgroups stratified into anatomic pulmonary resection and wedge lung resections/mediastinal-pleural procedures.

Table 1 summarizes demographics and perioperative outcomes of MME0 versus MME+ subgroups of patients ongoing anatomic resection or wedge resection/mediastinal procedures. Although there was no difference in demographics, surgical indications, pathologic details, LOS, or complications between the MME0 and MME+ groups, patients in the MME0 group required much fewer in-hospital opioids, particularly the schedule II subclass (hydromorphone, morphine, oxycodone) while reporting overall lower subjective pain. Further granular analysis of subjective pain levels, MME, and percentages of patients receiving opioid on the day of discharge of the entire study population and 2 subgroups stratified to types of surgical procedures is shown in Figure 2. Patients of the MME0 group reported a significantly lower level of pain as compared with MME+ group on the day of discharge (median [interquartile range]: 1.0 [0.0-1.7] to 1.0 [0.0-3.0] of MME0 groups versus 2.0 [0.3-3.6] to 2.5 [1.5-4.0] of MME+ groups, $P < .0001$) (Figure 2, *A*). This was associated with a much lower percentage of patents requiring opioids while in the hospital (34.5%-36.2% of the MME0 group vs 66.3%-70.5% of the MME+ group, $P < .0001$) (Figure 2, *B*) and the MME on the day of discharge (0.0 [0.0-5.0] in the MME0 group vs 7.5 [0.0-15.0] to 7.5 [0.0-22.5] in the MME+ group, $P < .0001$) (Figure 2, *C*). Among patients of the MME+ group, 57 (31%) filled scheduled II (oxycodone) prescriptions, 138 (75%) filled schedule IV (tramadol), including 9 who required both schedule II and

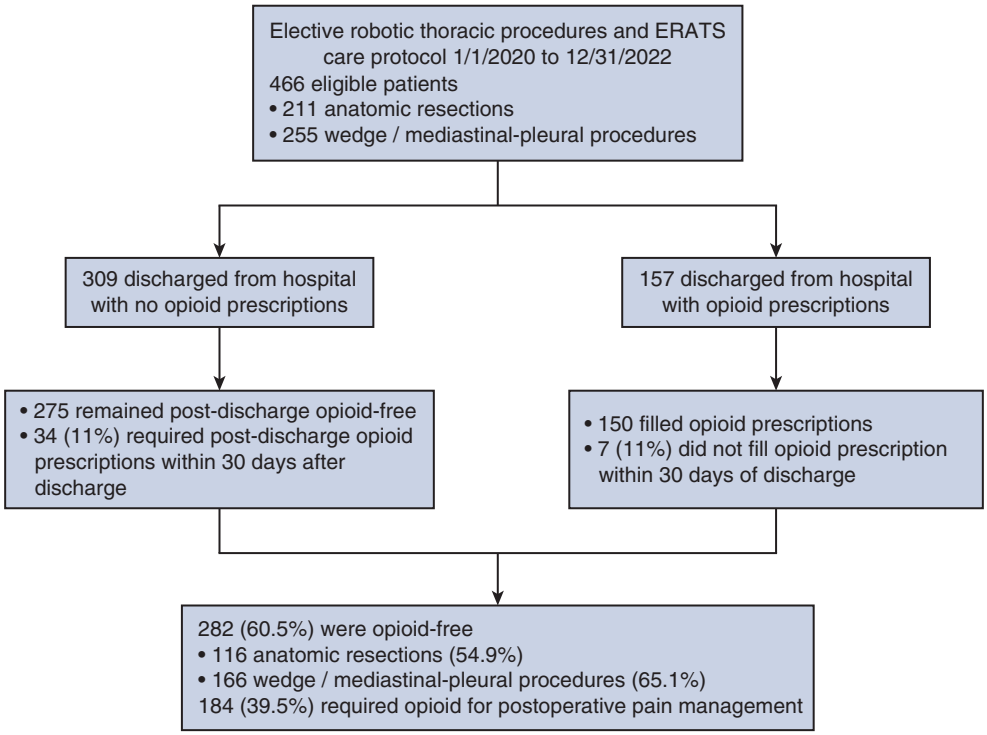

FIGURE 1. Consolidated Standards of Reporting Trials diagram. *ERATS*, Enhanced recovery after thoracic surgery.

TABLE 1. Demographics and clinical characteristics of MME0 and MME+ cohorts

Procedure	MME0 (n = 116)	MME+ (n = 95)	*P* value
Anatomic lung resections (n = 211)			
Age, y	66.0 (62.0-76.2)	67.0 (59.0-73.0)	.14
Sex (female:male)	67:49	53:42	.88
BMI, kg/m^2	26.7 (23.3-31.4)	27.5 (24.2-31.3)	.92
FEV1 (% normal)	90.0 (81.0-104.0)	88.5 (78.0-98.7)	.81
DLCO (% normal)	78.5 (69.0-91.7)	78.0 (65.0-93.0)	.96
Operating time	190.0 (153.7-237.0)	182.0 (151.0-232.5)	.47
ASA	3 (3-3)	3 (3-3)	.89
Indications			
Neoplasm, n (%)	113 (97.4%)	91 (95.8%)	.7
Primary	106	85	
Secondary	7	6	
Benign	3 (2.6%)	4 (4.2%)	
Stages			
0-1	74 (69.8%)	68 (80.0%)	.14
2	16	9	
3-4	16	8	
In-hospital analgesics			
Total MME	**10.2 (3.0-30.5)**	**30.0 (17.9-51.5)**	**<.0001**
Schedule 2 MME	**7.5 (1.5-24.5)**	**22.0 (9.4-43.6)**	**<.0001**
Schedule 4 MME	**0.0 (0.0-5.0)**	**5.0 (0.0-10.0)**	**<.0001**
NSAIDs, n (%)	77 (66.4%)	63 (66.3%)	.76
Acetaminophen, n (%)	114 (98.3%)	95 (100%)	.50
Pain			
POD0	**4.2 (2.8-5.5)**	**4.7 (3.4-6.0)**	**.0168**
POD1	**1.7 (0.8-3.0)**	**2.8 (1.7-4.0)**	**.00008**
POD2	**1.0 (0-2.7)**	**1.9 (0.9-3.4)**	**.039**
Perioperative outcomes			
LOS, d	2.0 (1.0-3.0)	2.0 (1.0-3.0)	.89
Complications, n (%)			
0	103 (88.8%)	81 (85.2%)	.26
1-2	9	12	
3-4	4	4	
Wedge resections/Mediastinal - pleural procedures (n = 255)	**MME0 (n = 166)**	**MME+ (n = 89)**	***P* value**
Age	63.0 (50.0-72.0)	60.5 (48.3-69.8)	.064
Sex (female:male)	93:73	51:38	.97
BMI, kg/m^2	26.5 (23.2-31.2)	27.4 (23.2-31.6)	.72
FEV1 (% normal)	86.0 (71.5-95.5)	90.0 (80.0-98.0)	.095
DLCO (% normal)	77.5 (66.0-85.5)	80.0 (66.0-89.3)	.77
Operating time	102.9 (77.0-139.9)	94.0 (75.0-135.0)	.67
ASA	3.0 (3.0-3.0)	3.0 (3.0-3.0)	.96
Indications			
Neoplasm, n (%)	101 (60.8%)	55 (61.8%)	
Primary	43	19	
Secondary	58	36	
Benign, n (%)	65 (39.2%)	34 (38.2%)	
In-hospital analgesics			
Total MME	**6.0 (1.2-18.0)**	**28 .0 (10.4-46.5)**	**<.0001**
Schedule 2	**4.6 (0-13.5)**	**27.5 (6.0-43.5)**	**<.0001**
Schedule 4	0.0 (0.0-5.0)	0.0 (0.0-5.0)	.92

(Continued)

TABLE 1. Continued

Wedge resections/Mediastinal - pleural procedures (n = 255)	MME0 (n = 166)	MME+ (n = 89)	*P* value
NSAIDs, n (%)	95 (57.2%)	58 (66.2%)	.23
Acetaminophen, n (%)	163 (98.2%)	89 (100%)	.55
Pain			
POD0	**4.0 (2.1-5.3)**	**5.2 (4.0-6.0)**	**<.0001**
POD1	**1.4 (0.3-3.1)**	**2.5 (1.6-4.0)**	**<.0001**
POD2	**0.4 (0-1.7)**	**1.7 (0.0-3.2)**	**.04**
Perioperative outcomes			
LOS	1.0 (1.0-2.0)	1.0 (1.0-2.0)	.47
Complications, n (%)			
0	157 (94.5%)	83 (93.2%)	.66
1-2	4	4	
3-4	5	2	

Demographics, clinical data, perioperative in-hospital analgesic use, subjective pain levels, and outcomes of patients undergoing elective robotic thoracoscopic anatomic lung resections or wedge lung resections of pleural–mediastinal procedures stratified into discharge with opioid prescription (MME+) or opioid-free pain management (MME0). Values are presented as number and percentages (n, %) or median and quartile 1-quartile 3 (interquartile range). Bold text indicates statistical significance. *MME*, Milligram morphine equivalent; *BMI*, body mass index; *FEV1*, forced expiratory volume in 1 second; *DLCO*, diffusing capacity of the lungs for carbon monoxide; *ASA*, American Society of Anesthesiologists; *NSAIDs*, nonsteroidal anti-inflammatory drugs; *POD*, postoperative day; *LOS*, length of stay.

schedule IV. Overall, only 12.7% (57/446) of the entire study cohort filled postdischarge schedule II opioid oxycodone.

A detailed analysis of postdischarge opioid use is summarized in Table 2. Significantly lower incidences of intermediate-term (31-180 days, $P = .022$) and long-term (181-365 days, $P = .0074$) opioid use as well as of new persistent opioid users were observed in the MME0 group (3.2% vs 10.8% of the MME+ group, $P = .0013$). The majority of MME0 new persistent opioid users were patients with metastatic cancers receiving various forms of systemic therapy (77.8%) as compared with MME+ patients similarly classified (30.0%, $P = .04$). After we excluded patients receiving opioids for indications unrelated to the index procedures, 15.9% of patients in our entire cohort filled prescriptions for opioids between 31 and 365 days' postoperatively, slightly greater in the MME+ group (21.2% vs 12.4% of the MME0 group), and the difference was not statistically significant ($P = .15$) A very low incidence of postoperative chronic users (2.36%) was seen in the entire cohort of opioid-naïve patients, with no difference observed between the MME0 versus the MME+ subgroups (1.24% vs 3.80% respectively, $P = .12$).

Univariable analysis to identify factors associated with MME0 in the whole cohort and the 2 subgroups is shown in Table 3. For the entire study cohort, wedge resection/mediastinal procedures, no opioid use, and pain level less than 1 on day of discharge were highly associated with MME0. In contrast, in-hospital subjective pain and opioid needs were associated with MME+, especially with increasing pain levels and opioid use on the day of discharge. These factors for MME0/MME+ were also observed following stratification into types of surgical procedures. After we adjusted for relevant factors, multivariable analysis identified increasing age, wedge resections/mediastinal procedures, very low or no subjective pain (visual pain scale <1), and <10 MME use on the day of discharge as associated with MME0 for the entire cohort and in the wedge resection/mediastinal subgroup. In contrast, only no opioid use on day of discharge was associated with MME0 in the anatomic resection subgroup (Table 4).

DISCUSSION

Since implementation of the newest version of our ERATS protocol on January 2020, we have achieved a rate of 60% opioid-free discharge following elective robotic thoracic procedures of diverse indications. This retrospective analysis identified clinical factors associated with safe discharge without opioids. These include wedge resection/mediastinal–pleural procedures, no in-hospital opioid use on day of discharge, and subjective pain level 1 or less of 10 based on visual analog scale pain score. Multivariable analysis identified no in-hospital opioid use on day of discharge as the only factor strongly associated with MME0 following anatomic resections. Our review also demonstrated that even in 184 patients discharged with opioid prescriptions, only 57 patients (31%) needed potent schedule II opioid within 1 month following the index operations, representing 12.7% of the entire study population of 446 patients. Finally, filling of additional opioid prescriptions between 1 and 12 months following the index robotic procedures ranged from 12.4% (MME0 group) to 21.2% (MME+ group), with a greater incidence of new persistent opioid users

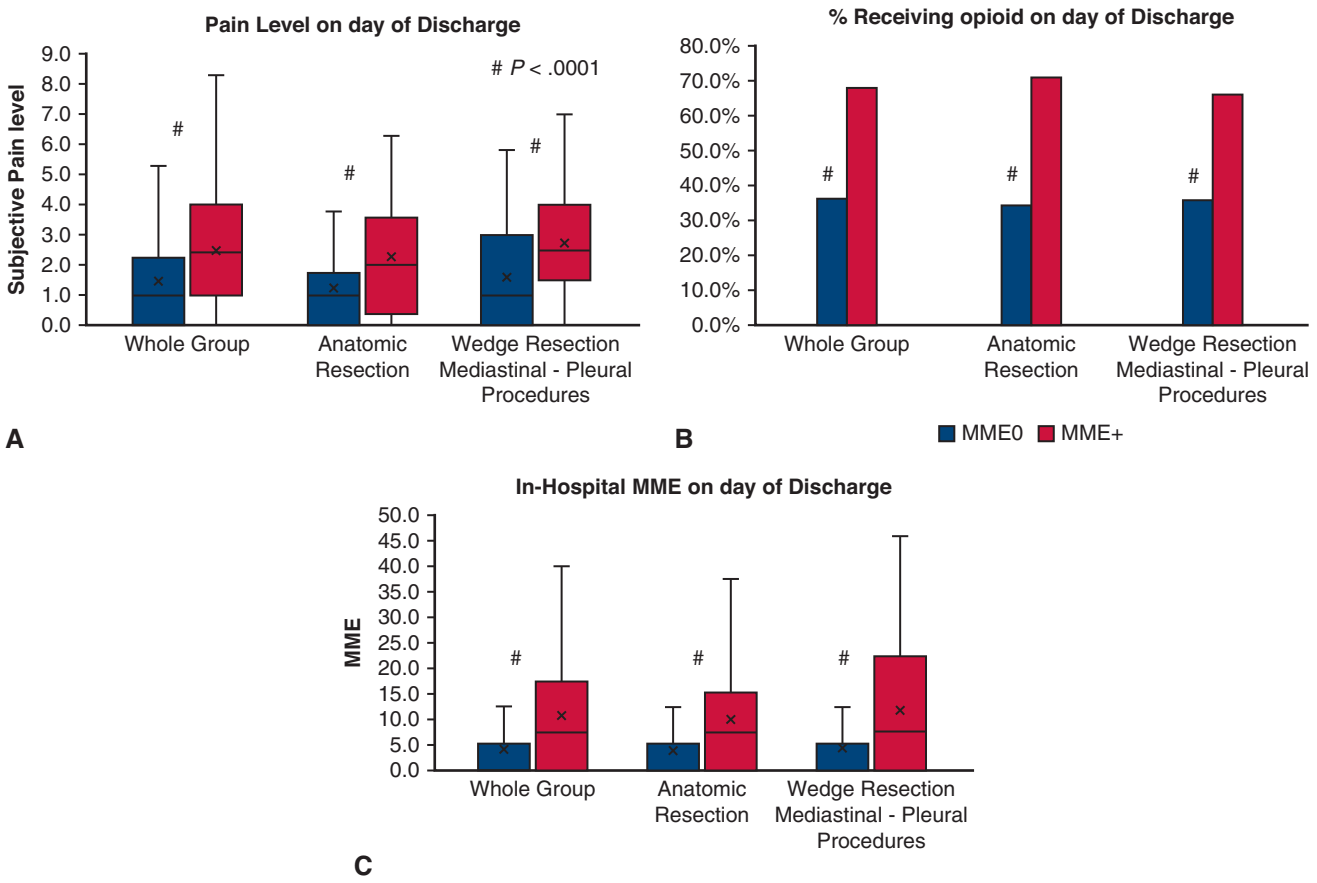

FIGURE 2. Comparative analysis of subjective pain levels (A), the amount of in-hospital opioid use (B), and the percentages of patients receiving opioid (C) on the day of discharge from hospital of the entire cohort and its subgroups following indicated robotic thoracoscopic procedures. Data are presented using box-whisker plots (median: –, mean: x); *vertical bars* indicate minimal and maximal values. *MME*, Milligram morphine equivalent.

observed in the MME+ subgroup. Only 2.3% of our opioid-naïve patients became chronic users.

Our original ERATS protocol has undergone 2 modifications as previously reported.[3,4,7,9] The last modification enabled us to drastically reduce the use of in-hospital opioids without affecting pain levels. As per our protocol, the need for postdischarge opioid prescription is guided by subjective pain levels and opioid use on the day of discharge. Comparative analysis of in-hospital opioid use by patients managed by the previous 2 ERATS protocols indicated that 96% took opioids on the day of discharge (in contrast to 47% of those in the current ERATS protocol) and that it was associated only 16% to 19% opioid-free discharges in these patient populations. The most consistent factor associated with MME0 by multivariate analysis is no opioid use on the day of discharge in the entire cohort and its subgroups. Very low or no pain (level <1) on day of discharge is also a predictive factor of MME0, but pain, being a complex physiologic and psychologic entity, may not always equate with patients willing to leave the hospital without an opioid prescription. Discharge without opioid prescription represents a mutual decision of the care providers and the patients that the postoperative discomforts, if at all significant, can be adequately managed without opioids after leaving the hospital. This can be readily achieved when patients do not need any opioids on the day of discharge and certainly very acceptable to patients when they have little or no pain before leaving the hospital. In-hospital opioid use frequently stems from pain not adequately managed with nonopioid analgesics and from patients' level of pain tolerance and aversion of opioids. Optimal pain control, in addition to minimizing reliance on opioids, is also essential for early ambulation, effective chest physical therapy, reducing postoperative complications, improving sense of well-being, and on-time discharge.

Further review of our database for similar patient population of the subsequent 12 months (January 1, 2022, to December 31, 2022; n = 316; 144 anatomic lung resections and 172 wedge resections/mediastinal–pleural procedures) shows the incidence of MME0 is 64.5%, affirming the

TABLE 2. Number of patients and incidence of intermediate- and long-term opioid use following discharge after elective robotic thoracoscopic procedures in opioid-naïve patients

Postoperative days	Total (n = 466)	MME0 (n = 282)	MME+ (n = 184)	*P* value
0-30	184 (39.48%)	0	184	
31-180	58 (12.4%)	27 (9.6%)	31 (16.8%)	**.022**
31-89	43 (9.2%)	21 (7.4%)	22 (11.9%)	.10
90-180	32 (6.8%)	12 (4.2%)	20 (10.8%)	**.008**
181-365	36 (7.7%)	14 (4.9%)	22 (11.9%)	**.0074**
Cumulative opioid users, days 31-356	74 (15.9%)	35 (12.4%)	39 (21.2%)	.15
New persistent opioid users	29 (6.2%)	9 (3.2%)	20 (10.8%)	**.0013**
Stage 4 cancers with/ without active therapy	11 (40.7%)	7 (77.8%)	6 (30.0%)	**.040**
Chronic opioid users	11 (2.3%)	4 (1.4%)	7 (3.8%)	.12
Stage 4 cancers with/ without active therapy	7 (63.6%)	2 (50.0%)	5 (71.4%)	.57

Intermediate- and long-term postdischarge opioid use in MME0 and MME+ patients. Discharge with opioid prescription was associated with increased incidence of new persistent opioid use. *P*: MME0 versus MME+, Fisher exact test. Bold text indicates statistical significance. *MME*, Milligram morphine equivalent.

consistency of our opioid-sparing discharge practice. The 11% incidence of patients discharged without opioids who would subsequently require an opioid prescription within 1 to 4 weeks after discharge, mainly low doses of tramadol (45-60 MME), indicates that patients were suitably discharged without opioids and identifying these patients would avoid overestimating the originally MME0 population. Moreover, 11% of patients who never filled their opioid prescription would not be otherwise identified without using the PDMP database and thus would underestimate the MME0 population. It is encouraging to observe that only 12% of all patients undergoing elective robotic thoracoscopic procedures relied on schedule II opioid for postdischarge analgesia. The median MME of this subgroup was only 90, equivalent to twelve 5-mg oxycodone tablets. Our observation is similar to the high incidence of opioid-free discharges as recent reported by Clark and colleagues.[13] Long-term tracking of opioid use in our opioid-naïve patient population indicated that 15.9% filled opioid prescriptions within 1 year after index operations. This is comparable with the 18% incidence of outpatient opioid used at 6 months as reported by Strobel and colleagues.[14] The incidence of new persistent opioid users in the MME+ cohort is 10.8%, similar to those reported by Brescia and colleagues[11] (9.4%, opioid-naïve, thoracoscopic lung resections); and by Turner and associates[15] (10.6%, opioid-naïve, ERAS, 86% opioid prescription on discharge, and 86% thoracoscopic approach). Most importantly is the low incidence of persistent opioid users of 3.2% of MME0 patients, almost 3-fold reduction from reported results and that of the MME+ cohort (Table 2). Moreover, patients with stage 4 cancers accounted for the majority of new persistent users of the MME0 group, recapitulating that adjuvant chemotherapy or radiation therapy is one of risk factors of chronic pain and persistent new opioid use after thoracic surgery.[16] Opioid-free discharges and schedule II–sparing outpatient prescriptions eliminate availability of potent, addiction-prone narcotics to the public and directly contribute to the fight against the opioid epidemic. This is an important achievement, marking a positive deviation from previous observations that thoracic surgical patients consumed large quantities of opioids for pain control and high incidences of outpatient opioid use were traced to inappropriately high MMEs prescribed by surgeons for postoperative pain management.[16] Our current ERATS protocol represents an active concerted effort, building on experience with the previous protocols, to minimize reliance on opioids while maintaining excellent pain control.

Our current effort focuses on mitigating immediate postoperative pain, classically most intense in the postanesthesia care unit, which is likely pleuritic discomfort due to the presence of the 28-F chest tube placed very low in the hemithorax and irritating the diaphragm.[17] Moreover, all appropriate intraoperative measures are taken to minimize air leak to facilitate early intrathoracic drain removal within a few hours after conclusion of thoracoscopic operations, especially following wedge lung resections or mediastinal procedures. Strategies to achieve pain <1 with minimal or no opioid use on day of discharge will likely increase the incidence of MME0 even greater than observed.

Our study has many limitations inherent to being retrospective in nature. Our study is a single institutional study and is representative of a very standardized practice pattern. Our database is audited by a single coauthor but has been

TABLE 3. Univariable regression analysis for factors for discharge from hospital without opioid prescription (MME0)

Characteristic	Overall			Wedge resections/ mediastinal–pleural procedures			Anatomic resections		
	OR	95% CI	*P* value	OR	95% CI	*P*-value	OR	95% CI	*P* value
Procedures									
Wedge vs anatomic	**1.53**	1.05-2.22	**.026**						
Age	1.01	1.00, 1.03	.056	1.02	1.00-1.05	.066	**1.02**	1.00-1.03	**.047**
Operating time, min	1	1.00-1.00	.4	1	1.00-1.01	.3	1	0.99-1.00	.7
LOS, d	1.01	0.94-1.11	.8	1.08	0.94-1.27	.3	1	0.90-1.12	>.9
In-hospital MME	**0.98**	0.98-0.99	**<.001**	0.99	0.98-1.00	.11	**0.97**	0.96-0.98	**<.001**
Schedule 2	**0.99**	0.98-0.99	**<.001**	1	0.99-1.00	.4	**0.97**	0.95-0.98	**<.001**
Schedule 4	**0.95**	0.92-0.97	**<.001**	**0.9**	0.85-0.95	<.001	0.98	0.95-1.01	.14
BMI, kg/m^2	1	0.97-1.03	.9	1	0.95-1.05	>.9	1	0.96-1.04	>.9
FEV1 (% pred N)	1	0.98-1.01	.6	1.01	0.99-1.02	.5	0.99	0.97-1.01	.2
DLCO (% pred N)	1	0.99-1.01	>.9	1	0.99-1.02	.6	1	0.98-1.01	.7
POD0 pain level	**0.77**	0.69-0.85	**<.001**	**0.82**	0.70-0.96	**.013**	**0.72**	0.62-0.83	**<.001**
POD1 pain level	**0.76**	0.68-0.84	**<.001**	**0.76**	0.64-0.89	**<.001**	**0.76**	0.66-0.88	**<.001**
Pain level on day of discharge	**0.74**	0.66-0.82	**<.001**	**0.68**	0.57-0.81	**<.001**	**0.75**	0.64-0.86	**<.001**
MME on day of discharge	**0.93**	0.91-0.95	**<.001**	**0.93**	0.89-0.96	**<.001**	**0.93**	0.90-0.96	**<.001**
No MME on day of discharge	**4.28**	2.89-6.40	**<.001**	**5.47**	3.05-10.0	**<.001**	**3.48**	2.04-6.04	**<.001**
Pain level <1 on day of discharge	**2.89**	1.93-4.37	**<.001**	**2.52**	1.44-4.46	**.001**	**3.81**	2.09-7.25	**<.001**
Pain level on day of discharge									
<1		–	–		–	–		–	–
1-3	**0.49**	0.30-0.78	**.003**	0.64	0.33-1.21	.2	**0.36**	0.17-0.71	
3+	**0.28**	0.17-0.46	**<.001**	**0.2**	0.09-0.43	**<.001**	**0.29**	0.14-0.58	
MME on day of discharge									
0-10	**0.38**	0.23-0.63	**<.001**	**0.23**	0.11-0.48	**<.001**	0.64	0.30-1.37	.2
>10	**0.17**	0.10-0.26	**<.001**	**0.15**	0.07-0.31	**<.001**	**0.18**	0.09-0.33	**<.001**

Univariable analysis for factors associated with MME0 following elective robotic thoracoscopic procedures. Univariable analysis revealed increased pain score and high MME usage on day of discharge were associated with decreased incidence of opioid free discharge in both anatomic and wedge/mediastinal resection groups. Conversely lack of MME usage and low pain score was associated with MME0 discharge. Bold text indicates statistical significance. *OR*, Odds ratio; *CI*, confidence interval; *LOS*, length of stay; *MME*, milligram morphine equivalent; *BMI*, body mass index; *FEV1*, forced expiratory volume in 1 second; *DLCO*, diffusing capacity of the lungs for carbon monoxide; *POD*, postoperative day.

validated by concordance with outside data and previous publications. Furthermore, all nonblinded retrospective studies suffer from potential for bias, and our work is no exception. Finally, our patient population is of more advanced age, which may impact opioid-usage patterns.[18] The strengths of our study include robust audited single-

TABLE 4. Multivariable regression analysis for factors associated with discharge home without opioid prescription (MME0)

Characteristic	Overall (n = 466)			Wedge resections/mediastinal–pleural procedures (n = 255)			Anatomic resections (n = 211)		
	OR	95% CI	*P* value	OR	95% CI	*P*-value	OR	95% CI	*P* value
Anatomy									
Wedge (vs lobe)	**2.18**	1.30-3.69	**.003**						
Age	**1.02**	1.00-1.03	**.023**	**1.02**	1.00-1.04	**.034**	1.02	0.99-1.05	.2
Operating time, min	1	1.00-1.00	.6	1	0.99-1.00	.5	1	1.00-1.01	.4
BMI, kg/m^2	0.99	0.95-1.02	.5	0.97	0.93-1.02	.3	1	0.94-1.06	>.9
LOS, d	1.01	0.93-1.13	.8	0.98	0.88-1.12	.7	1.05	0.91-1.28	.5
Pain level <1 on day of discharge	**2.04**	1.31-3.21	**.002**	**3.05**	1.57-6.14	**.001**	1.68	0.89-3.15	.11
MME on day of discharge									
10+	–	–		–	–		–	–	
1-10	**2.2**	1.25-3.93	**.007**	**4.1**	1.82-9.68	**<.001**	1.36	0.58-3.21	.5
0	**4.88**	2.99-8.05	**<.001**	**4.13**	2.12-8.18	**<.001**	**5.47**	2.66-11.6	**<.001**

Multivariable regression analysis for predictive factors of MME0 following elective robotic thoracoscopic procedures. Multivariable analysis revealed wedge vs lobe, younger age, low pain level, and 0-10 MME usage on day of discharge was associated with MME0 discharge. Bold text indicates statistical significance. *OR*, Odds ratio; *CI*, confidence interval; *BMI*, body mass index; *LOS*, length of stay; *MME*, milligram morphine equivalent.

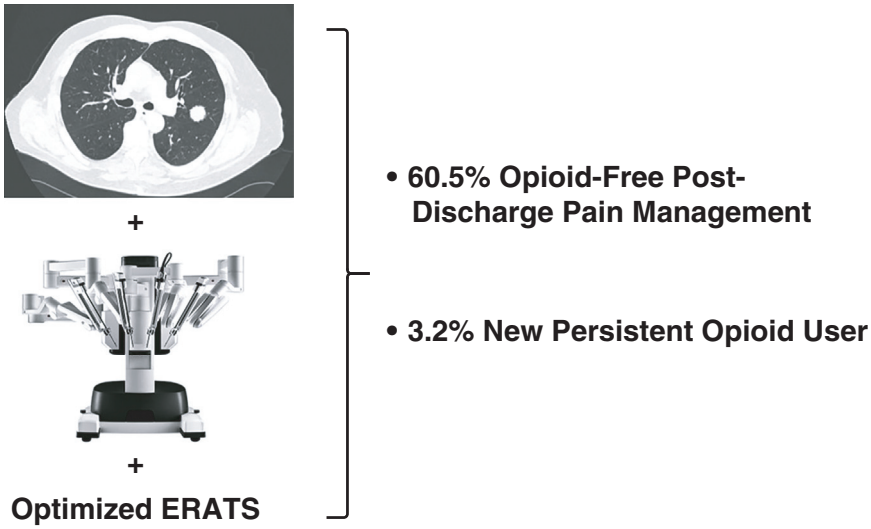

FIGURE 3. Optimized ERATS protocols increase opioid free discharges and decrease persistent opioid use. *ERATS*, Enhanced recovery after thoracic surgery.

institution data with robust auditing of data and strong follow up by our advanced practice registered nurses. Furthermore, the ability our ability to analyze ongoing optimization efforts highlighting the longitudinal effects on opioid use is extremely valuable. Our access to granular data regarding controlled prescription fills and more importantly refills in our patients thanks to our electronic medical record and state physician reporting system is nearly unique.

CONCLUSIONS

A salutary outcome of our current ERATS protocol with very low in-hospital postoperative opioid requirements and satisfactory pain control is the ability to safely discharge 60% of patients after diverse elective robotic thoracoscopic procedures without any opioids (Figure 3). No opioid use and minimal or no pain on the day of discharge are strongly associated with successful opioid-free outpatient pain management of this patient population. Moreover, MME0 was associated with a very low incidence of new persistent opioid users. Our work highlights the importance of ERATS optimization to combat the national epidemic of opioid addiction while providing our patients with a near–pain-free postoperative experience.

Conflict of Interest Statement

The authors reported no conflicts of interest. The authors discuss the off-label use of liposomal bupivacaine (LipoB) (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 protocol, robotic thoracic surgery, opioid, liposomal bupivacaine, intercostal nerve block, pulmonary lobectomy, pulmonary wedge resection, postoperative pain, postoperative opioid use

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 hour before surgery)
Gabapentin: 100 mg (1 hour 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
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 Q8hrs
Tramadol 50 mg PO Q6hrs PRN (pain scale <4)
Ibuprofen 600 mg PO Q8hrs postoperatively or Toradol 15 mg Q6hrs 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 Q8hrs; titrating greater doses based on tolerance to achieve control of neuropathic pain
Oxycodone 5 mg PO Q6hrs PRN (pain scale: 4-6)
Oxycodone 10 mg PO Q6hrs PRN (pain scale: 7-10)
Morphine 2-4 mg IV Q6hrs PRN or hydromorphone 0.5-1.0 mg IV or 2-4 mg PO Q6hrs PRN for breakthrough pain
Heparin 5000 U subcutaneous Q8h
Metoprolol 12.5 mg Q12hrs (if not already on a beta-blocker following anatomic resection)
Tamsulosin 0.4 mg QD (>50 year 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 $\leq$90% on room air with ambulation
Chest tube removal (no air leak off –20 cm suction on postoperative day 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 Q4hrs to Q6hrs 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 Q8hrs for 20 d
Tramadol 50 mg PO Q6hrs for 3 d (12 tablets; if used postoperatively in-hospital)
Gabapentin 100 mg PO Q8hrs for 60 d (30 d supply refill $\times$1); titrated up to address neurogenic pain
Ibuprofen 600 mg PO Q8hrs for 20 d
Oxycodone 5 mg PO Q6hrs 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

PO, Per os (orally); *q*, every; *hr*, hour; *PRN*, pro re nata (as needed); *IV*, intravenously; *POD*, postoperative day; *APRN*, advanced practice registered nurse.

TABLE E2. Discharge instructions

You just had a chest operation. You may have had robotic thoracoscopic surgery or video-assisted thoracoscopy (small incisions) or an open thoracotomy (long incision). The aim of this list of instructions is to make your postoperative recovery tolerable.
Pain: Incisional pain will rapidly reduce within a week after surgery. Nerve pain (burning, flashing, pin-and-needle, pressure sensation in the front along the rib cage and beneath your breast) is to be expected. The following medications are prescribed for pain control: Neurontin (gabapentin): to take as prescribed regularly every 8 h for nerve pain Tylenol (acetaminophen): to take as prescribed regularly every 8 h for pain Celebrex (Celecoxib): to take as prescribed regularly twice daily for pain or ibuprofen (Motrin) to take as prescribed regularly 3 times a day (Protonix (Pantoprazole): Take as prescribed. One capsule daily while taking pain medications to reduce the risks of stomach irritation) Tramadol, oxycodone, or hydrocodone are narcotics, and they are strictly controlled by the state of Florida and only 3 to 5 days' supply is prescribed for you. It is prescribed "as needed" only for pain not controlled with the other medications.
Wound care: Your incisions are covered with a water-resistant glue. There is only a small dressing covering a small incision with a short stitch (left behind after removal of the chest tube). This dressing should be removed in 48 h following chest tube removal. You can take a shower at home and change the hospital dressing with a simple baby Band-Aid. Never leave a moist dressing on your wound. It will promote wound infection.
Heart function: Some operations like lung lobectomy, pneumonectomy, or esophagectomy are associated with risks for abnormal heart beating, such as fast rhythm called atrial fibrillation. You may have been prescribed a very low dose (12.5 mg or less frequently 25 mg twice a day) of a medication called metoprolol (Lopressor) to reduce that risk. It belongs to a class of drug called beta blockers. Its main effect is to reduce heart rate and blood pressure. If you were not taking it before surgery, we usually stop this medication 4 weeks after surgery when risk is reduced. Some people experience adverse reactions to this medication such as dizziness; please call nurse practitioner for advice.
Bowel function: Stool softeners like docusate sodium, MiraLAX, and Bisacodyl (Dulcolax) are prescribed for you and used as directed to avoid constipation for 5 days following discharge. Never let constipation last more than 2 days, call nurse practitioner if needing medical advice.
Strict aspiration precautions at home: Eat or drink only upright position and wait 4 hours after eating/drinking before going to sleep. Elevate the head of the bed 7 inches.
Bladder function: You should drink adequate amount of liquids to avoid dehydration and constipation. Flomax may have been prescribed for men to avoid urinary retention. This medication is stopped upon discharge if no urinary retention is documented.
Physical activity: You are expected to gradually increase your level of physical activity. Avoid being inactive, as this increases the risk of blood clot in the leg (deep-vein thrombosis). Also avoid overexertion, as this will increase incisional pain.
Respiratory exercises: You are expected to use the incentive inspiratory device  at least 15-20 times per hour following surgery. You will continue using this device up to 4 weeks after discharge to prevent pneumonia and atelectasis. This device will be provided to you on your preoperative clinic visit for you to start practicing.
Others important reminders: If you were taking Plavix or other blood-thinning medications before surgery, you should get specific instructions about when it is safe to resume them. Your blood pressure and your blood sugar may change during the first few days after surgery. It is important that you check them frequently if you suffer high blood pressure and/or diabetes and visit your primary care physician to adjust medications as needed.
Follow-up visit: Appointments will be requested to clinic upon discharge by nurse practitioner. The surgical coordinator will contact you from our clinic to confirm the date and time of the follow up appointment and scheduled radiograph.
if questions regarding appointments, follow up, x-rays, upcoming surgical procedures etc… please contact our office at: XXX-XXX-XXXX
if clinical questions like pain management, wounds, urgencies etc… please contact our inpatient nurse practitioner:
Practitioner #1, APRN XXX-XXX-XXXX
Practitioner #2, APRN XXX-XXX-XXXX
Either of us will call you by indicated phone number in the medical record to check on you at least twice after your discharge (usually postoperative day 2 and postoperative day 5) until you see your surgeon around postoperative day 10-14.