

Roadmap to the Enhanced Thoracic Surgical Journey

TACHARRA Y. D. WOODARD, MSN, APRN, ACNP-BC, AOCNP®,
CARLA M. PATEL, MSN, APRN, ACNP-BC, and GARRETT L. WALSH, MD

From The University of Texas MD Anderson Cancer Center, Houston, Texas

Authors' disclosures of conflicts of interest are found at the end of this article.

Correspondence to: TaCharra Y. D. Woodard, MSN, RN, ACNP-BC, The University of Texas MD Anderson Cancer Center, 1515 Holcombe Boulevard, Houston, TX 77030.

E-mail: tcwoodard@mdanderson.org

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Abstract

The Enhanced Recovery Program (ERP) is a comprehensive, multidisciplinary approach that directly impacts the functional recovery and quality of life of patients after surgery. Initiated in 2013 at The University of Texas MD Anderson Cancer Center by the Liver Surgery group and expanded to numerous specialties, the Thoracic and Cardiovascular Surgery Department developed a version of Enhanced Recovery After Thoracic Surgery in 2014. The benefits gained thus far include (1) decreased postoperative complications, (2) reduced hospital length of stay, (3) decreased opioid usage, (4) decreased healthcare costs, and (5) improved patient satisfaction. This article aims to provide a brief description of the history of the enhanced recovery approach and to identify the critical elements of the program necessary for improved patient care. It is intended to serve as a practical guide for program implementation in thoracic surgery departments at other institutions.

The Enhanced Recovery Program (ERP) is a comprehensive, multidisciplinary approach that directly impacts the functional recovery and quality of life of patients after surgery. The evidence-based interventions throughout each phase of the perioperative journey synergistically work to improve the patient's surgical experience and permit a quicker return to normal activities of daily living and the intended oncologic treatment if necessary (Shepherd, Klein, & Martinez, 2017). At The University of Texas MD Anderson Cancer Center in Houston, the program is expanding to include numerous surgical and medical specialties. The ERP engages patients and their families or caregivers in treatment planning and care delivery (Amaku & Recinos, 2018). The success of the program has been a positive endeavor within MD Anderson Cancer Center's Department of Thoracic and Cardiovascular Surgery. This Review article aims to provide a brief history of the enhanced recovery approach, identify the critical elements of the program, and serve as a practical guide for program implementation in thoracic surgery departments at other institutions.

HISTORICAL PERSPECTIVE

The enhanced recovery model of care was initiated by general surgeons in Northern Europe in 1997 researching strategies to improve the body's reaction to surgical stress by optimizing the patient's nutritional status, controlling pain with nonopioid techniques, and initiating early postoperative feeding (Taurchini, Del Naja, & Tancredi, 2018). With notable improvements in the time and quality of recovery after surgery, the enhanced recovery model's success led to the development of the ERAS Society in 2010 in Orebro University Hospital in Sweden, which aided in the dissemination of information throughout the world (Taurchini et al., 2018). In 2013, the first United States symposium was held in Washington, DC.

That same year, The University of Texas MD Anderson Cancer Center started the ERP with five fundamental principles to improve recovery: (1) patient education and engagement, (2) multimodal opioid-sparing analgesia, (3) rational fluid therapy, (4) risk-adjusted pathway-based postoperative care, and (5) rapid rescue from postoperative complications (Russell, 2019). This systematic implementation was initiated by the Gastrointestinal Cancer Center's Liver Surgery group. The program now includes 16 surgical specialties and 3 nonsurgical specialties.

The Department of Thoracic and Cardiovascular Surgery began multidisciplinary implementation team workshops in 2013, followed by structured educational sessions and implementation of the Enhanced Recovery After Thoracic Surgery (ERATS) program in 2014. In 2018, 816 thoracic surgical procedures were performed under ERATS (Amaku & Recinos, 2018). The benefits of the program have been a 21-fold reduction in the median in-hospital opioid usage, 50% reduction in patients discharged with opioids, a 28% improvement in the average pain score, minimization of fluid overload, decreased length of hospital stay, and a reduction in health-care costs and decreased cardiac and pulmonary complications after surgery (Amaku & Recinos, 2018; Van Haren et al., 2018). The success of the program required support from all levels of care, including nursing, anesthesia, surgery, trainees, pharmacy, nutrition, hospital administration, and, most importantly, patients and caregivers.

PREOPERATIVE AND INTRAOPERATIVE TECHNIQUE

Patient education sets expectations and engages patient participation, which is required to ensure the success of ERATS. As previously stated, each phase of the perioperative journey works synergistically to improve the patient's outcome. This education begins in the preoperative clinic appointment and continues throughout the perioperative course, as well as a follow-up post-discharge. This section will briefly discuss the effects of crucial preoperative and intraoperative management techniques on the postoperative outcome.

Avoidance of Preoperative Fasting

Recent studies have shown that the avoidance of fasting in the preoperative setting improves patient satisfaction and well-being, as well as reduces postoperative nausea and vomiting (Hausel, Nygren, Thorell, Lagerkranser, & Ljungqvist, 2005). Major surgery activates a stress response that will incite hyperglycemia and insulin resistance, which can lead to a higher incidence of postoperative complications (Ljungqvist, Scott, & Fearon, 2017). Evidence has shown that oral intake of clear liquids up to 2 hours before surgery is safe and does not increase gastric contents, which historically has been felt to increase the risk of aspiration events (Batchelor et al., 2019).

To decrease the likelihood of insulin resistance and to maintain metabolic stability, current practice for the nondiabetic patient undergoing thoracic surgery under ERATS is to receive carbohydrate loading. The patient consumes 800 mL of a 12.5% carbohydrate-containing clear drink the evening before surgery and an additional 400 mL 2 hours before scheduled check-in time (Batchelor et al., 2019). Contraindications for carbohydrate loading include achalasia, dysphagia, gastroparesis, obstructive gastrointestinal symptoms, procedures to the esophagus, stomach or duodenum, esophagogastric resection or bypass, and patients on fluid restriction (McCormick, 2017).

Multimodal Opioid-Sparing Analgesia

Multimodal pain control with opioid-sparing analgesia reduces postoperative complications and optimizes recovery, allowing a faster return to

preoperative functional status. In the preoperative area, patients are provided oral medications 1 to 2 hours before the procedure as part of the multimodal analgesia regimen. These medications include acetaminophen 1,000 mg, celecoxib (a cyclooxygenase-2 [COX-2] inhibitor) 200 mg, gabapentin immediate-release (a GABA analog) 300 mg, and tramadol extended-release (an opiate agonist) 300 mg. Lexicomp (2019) provides detailed information on each medication, as summarized in Table 1. Additional detailed information will be provided in the postoperative technique section.

Anesthetic/Fluid Management

The most impactful intraoperative anesthetic interventions on the success of ERATS include opioid-sparing strategies, multimodal analgesia, total intravenous anesthesia (TIVA), and goal-directed fluid therapy.

Preanaesthetic anxiolytics are not common practice under ERATS due to the advanced age of the thoracic surgical patient, the association with increased time to extubation, and the decreased rate of early cognitive recovery with use (Batchelor et al., 2019). Short-acting TIVA is conducted using potent and proven opioid-sparing analgesia, anti-inflammatory, antioxidant pharmacologic agents such as dexmedetomidine, propofol, and ketamine to permit early extubation before leaving the operating suite.

Anesthesia personnel avoid salt and fluid overload with the goal of euvolemia to prevent interstitial and alveolar edema postoperatively. Prevention of hypotension, which could lead to impaired tissue perfusion and organ dysfunction, is managed with vasopressors and a limited amount of fluid (Batchelor et al., 2019). Hemodynamic optimization is achieved utilizing minimally and noninvasive devices by anesthesia combined with

Table 1. Enhanced Recovery After Thoracic Surgery (ERATS) Medications

Medication	Contraindication	Adverse effects > 10%	Dosing considerations
Acetaminophen	Hypersensitivity to acetaminophen or any component of the formulation; severe hepatic impairment or severe active liver disease	Oral formulation frequency not defined; well-tolerated	<ul style="list-style-type: none"> Health-care professionals may prescribe or recommend 4 g daily maximum Use with severe caution in hepatic impairment
Celecoxib	Hypersensitivity to celecoxib, sulfonamides, aspirin, other NSAIDs, or any component of the formulation	No adverse events > 10%; most common is dyspepsia	<ul style="list-style-type: none"> Use not recommended for severe or advanced renal impairment Dose should be reduced by 50% for moderate hepatic impairment and not recommended for severe impairment
Gabapentin	Hypersensitivity to gabapentin or any component of the formulation	Dizziness, drowsiness, ataxia, fatigue	<ul style="list-style-type: none"> Dosing adjustment based on creatinine clearance required for renal impairment Some experts avoid use in patients > 65 years of age or reduce the dose
Tramadol	Hypersensitivity (e.g., anaphylaxis) to tramadol, opioids, or any component of the formulation; concomitant use with or within 14 days following MAO inhibitor therapy	Dizziness, vertigo, headache, drowsiness, CNS stimulation, constipation, nausea, vomiting, xerostomia, dyspepsia, weakness	<ul style="list-style-type: none"> Maximum daily dosage is 400 mg/24 hours Dosing adjustment based on creatinine clearance required for renal impairment In patients > 75 years of age, the maximum daily dosage is 300 mg/24 hours For severe impairment (Child-Pugh class C), usage avoided

Note. NSAIDs = nonsteroidal anti-inflammatory drugs; MAO = monoamine oxidase inhibitor; CNS = central nervous system

validated algorithms to guide fluid management.

Maintenance of normothermia is monitored with a temperature-censored Foley catheter in catheterized patients, esophageal temperature probe when a Foley catheter is not used, and a body warmer device, such as the 3M Bair Hugger system.

Postoperative nausea and vomiting (PONV) preventive measures include the administration of short-acting volatile anesthetics such as desflurane, short-acting opioids, IV antiemetics such as ondansetron, a selective 5-HT₃ receptor antagonist, 4 mg IV near the end of the case, and a single dose of an anti-inflammatory/antiemetic agent such as dexamethasone 8 mg IV. For patients with higher risk factors for PONV, such as female gender, prior history of PONV, nonsmoking status, age less than 50 years, and history of motion sickness (Gan et al., 2014; Tateosian et al., 2018), the addition of an anticholinergic such as scopolamine transdermal patch 1.5 mg behind the ear is added for PONV prophylaxis. The use of scopolamine may be inappropriate in the elderly and is contraindicated in patients with narrow-angle glaucoma (Tateosian et al., 2018).

Achieving high compliance with all of the techniques, as mentioned above, is critical to the success of ERATS. Poor compliance can lead to prolonged emergence, PONV, respiratory depression, the over-administration of opioids, and other complications as detailed previously.

Liposomal Bupivacaine

Liposomal bupivacaine, the cornerstone of ERATS, was first approved by the U.S. Food & Drug Administration in October of 2011 for administration into the surgical site to produce postsurgical analgesia (Pacira Pharmaceuticals, Inc., 2011). Since 2012, the use of liposomal bupivacaine has evolved from select minimally invasive thoracic surgical cases to routine usage in open thoracic procedures by all thoracic surgeons at MD Anderson Cancer Center by September of 2015. Nearly every thoracic surgical procedure being performed at MD Anderson Cancer Center utilizes liposomal bupivacaine as a critical component of ERATS. The dramatic transition from epidural usage, a decrease from 95% to 2% at present, to multilevel intercostal nerve blockade and wound infiltration with liposomal bupivacaine performed

by the thoracic surgeon at the time of surgery has maintained optimal pain management while improving mobility, avoided blood pressure variability that often required interruption of the epidural and administration of fluid boluses, reduced catheterization, and decreased postoperative opioid consumption. The analgesic effects of the intercostal nerve blockade with liposomal bupivacaine last up to 72 to 96 hours. Liposomal bupivacaine can be diluted with normal saline up to a volume of 250 mL and can also be mixed with 0.5% or 0.25% bupivacaine for immediate effect.

POSTOPERATIVE CARE

Postoperative interventions enhance patient recovery and rehabilitation. In the postoperative setting, compliance with the following discussed components of ERATS has the most substantial impact on success (Aarts et al., 2018).

Promotion of Early Oral Intake and Fluid Control

Fluid management after thoracic surgery can be a challenge. Careful attention to avoid over- and under-resuscitation is key to optimal fluid management. A key component of ERATS is the resumption of oral intake as soon as safely possible (Teeter, Kolarczyk, & Popescu, 2019). Patients are permitted a clear liquid diet upon admission to the thoracic surgery unit with advancement to a regular diet on postoperative day one if there are no contraindications. This eliminates the need for excessive intravenous fluid replacements. Patients are prescribed balanced crystalloid intravenous hydration at a rate of 40 mL/hour with the cessation of intravenous hydration by 9:00 am on postoperative day one if oral intake is tolerated and postoperative assessment and labs are stable. If a patient demonstrates hypotension that is not related to surgical bleeding or a cardiovascular event, conservative fluid replacement then judicious vasopressor therapy should be considered (Iyer & Yadav, 2013).

Early Mobilization

Early postoperative mobilization is key to decreasing morbidity after thoracic surgery. As early as 1949, Leithauser explained the benefit of early ambulation at a time when bed rest was the standard

of care for many routine procedures, including childbirth. Early mobilization lessens the chances of physical deconditioning, pulmonary and gastrointestinal complications, and venous thromboembolism (Batchelor et al., 2019). The standard of care on the thoracic surgery unit requires the nursing staff to ambulate postoperative patients within 4 hours of admission from the post-anesthesia care unit (PACU). Patients are expected to ambulate a minimum of four separate occasions on the nursing unit daily and are encouraged to travel to numerous in-hospital facilities for exercise and relaxation.

Venous Thromboembolism Prophylaxis

The reported incidence of venous thromboembolism after thoracic surgery carries a risk of 0.4% to 51% for deep venous thrombosis and up to 1% to 5% for pulmonary embolism (Batchelor et al., 2019). All thoracic surgical patients should receive venous thromboembolism prophylaxis unless there is a definite contraindication. Heparin 5,000 international units is initiated subcutaneously in the operative suite by anesthesia and continued throughout the hospital course at a dosing interval of every 8 hours. Intermittent pneumatic compression devices are also utilized during periods of immobility, including at rest in bed and during the night. Due to the risk of skin and tissue injury, the division of surgery has moved away from the use of antiembolism stockings. With these practices, the incidence of venous thromboembolism in 2019 at MD Anderson Cancer Center was 0.12% for deep venous thrombosis and 0.23% for pulmonary embolism (Tang & Correa, 2019).

Antibiotic Prophylaxis

Antibiotic prophylaxis is an evidence-based guideline used to prevent surgical site infections for all surgical cases. Timing and redosing are critical aspects of its use. The most recent American Society of Health-System Pharmacists (ASHP) Therapeutic Guidelines state that the optimal timing for preoperative antibiotic dosing is within 60 minutes of the surgical incision (Bratzler et al., 2013). Certain agents such as vancomycin may take up to 2 hours to infuse, so this must be taken into consideration when deciding on the infusion start time of the medication. Redosing should also be considered

for procedures that last longer than 2.5 half-lives of the agent being used or if there is massive blood loss. This should be discussed during the time-out process at the start of the procedure. The duration of prophylaxis at MD Anderson Cancer Center is 24 hours.

A facility-specific antibiogram is used to determine which agents are most effective against bacterial strains seen at MD Anderson Cancer Center. The current practice for thoracic surgical procedures is to administer ampicillin/sulbactam 1 g IV every 6 hours for four doses as the primary choice. A combination of ciprofloxacin 400 mg IV every 12 hours for two doses and vancomycin 1 g IV every 12 hours for two doses is used for patients who have a penicillin or cephalosporin allergy or have been colonized with methicillin-resistant *Staphylococcus aureus* within the past year.

Chest Physiotherapy

Chest surgery is associated with multiple potential lung-specific complications such as hypoxemia, atelectasis, bronchospasm, pneumonia, acute respiratory distress syndrome, and respiratory failure. Many of the patients presenting for chest surgery have preexisting comorbidities such as chronic obstructive pulmonary disease (COPD) and a smoking history. Vaporciyan and colleagues (2002) showed that smoking within 1 month of surgery was a significant predictor for major pulmonary complications postoperatively in patients undergoing pneumonectomy. Based on this knowledge, patients who are identified to be active smokers preoperatively are counseled to stop and are referred to our institutional smoking cessation program. If the surgical procedure is elective, the patient may be scheduled 3 to 4 weeks ahead to allow time to stop smoking and reduce their risk.

Patients are placed on albuterol sulfate and ipratropium bromide nebulizer treatments every 6 hours. Patients are mandated to use their incentive spirometer and Aerobika oscillating positive expiratory pressure therapy system hourly while awake. The patient's family members are employed to participate and act as pulmonary hygiene coaches, reminding the patient to perform their breathing exercises. Patients with COPD on bronchodilators have them restarted immediately postoperatively. Close collaboration with the re-

spiratory therapy department determines which patients require escalation of therapy based on the surgical team's assessment as well as a respiratory therapy algorithm. Patients found to have tenacious secretions may be started on mucolytics such as acetylcysteine or guaifenesin, receive nasotracheal suctioning, or receive a therapeutic awake bronchoscopy. For those patients who need additional assistance with lung expansion, the MetaNeb System is employed.

Foley Management

Foley catheters are traditionally used intraoperatively to monitor urine output for all major surgical procedures. However, use of urinary catheters is associated with multiple problems such as urethral injury during placement, increased risk for urinary tract infection, recatheterization due to retention triggered by urethral manipulation in males with benign prostatic hypertrophy (BPH), discomfort, restriction of patient mobility, and a delay in hospital discharge (Sanchez et al., 2018; Tammela, Kontturi, & Lukkarinen, 1986). Screening occurs in the preoperative setting to determine which patients can forgo having a catheter placed at the time of surgery. Criteria for not placing a Foley include straightforward lung surgeries, procedures expected to last 4 hours or less, and those where major blood loss is not anticipated. Exclusion occurs for patients in whom strict intake and output monitoring is critical, such as patients undergoing pneumectomy, esophagectomy, pleurectomy decortication, and chest wall resection, as well as those patients with baseline renal insufficiency or who have had a nephrectomy.

If an intraoperative Foley catheter is clinically indicated, every effort is made to discontinue the catheter as soon as possible. An early Foley removal protocol is followed postoperatively. The catheter is removed on postoperative day one and the protocol is ordered that allows the nurse to enact interventions based on the patient's condition. Patients are expected to void 8 hours after catheter removal. If they fail to meet this deadline, a bladder scan is performed. If the scan shows less than 200 mL of urine, the patient receives a 500 mL fluid bolus of normal saline. If the bladder scan shows more than 200 mL of urine but

less than 500 mL, the bladder is scanned every 2 hours until either the patient voids or reaches the threshold for catheterization. If the scan reveals greater than 500 mL of urine, intermittent straight catheterization is performed. Once this occurs, the clock starts over and the patient has an additional 8 hours to void. If the patient fails to void during that time period, a Foley catheter is reinserted. Patients with a history of BPH are restarted on their home medications immediately postoperatively. For patients who do not take any medications but endorse symptoms, tamsulosin 0.4 mg is initiated by mouth daily for the duration of the hospital stay. Figure 1 demonstrates the pathway.

Chest Tube Management

Chest tubes are generally required for all procedures that violate the thoracic cavity and are placed to evacuate air and drainage from the chest. The fluid can range from simple serous, transudative fluid to exudative fluids such as blood, chyle, and purulence. Exudative fluid must be dealt with differently and on a case-by-case basis that is beyond the scope of this article. Transudative fluid is always present in the pleural space. The reabsorption is accomplished by the parietal pleural lymphatics with an average turnover rate of 0.15 mL/kg/hour. Reabsorption can increase using a negative feedback system to control the additional pleural fluid generated from the inflammation caused by surgery (Miserocchi, 1997). Every center performing chest surgery has a threshold of chest tube drainage at which they are comfortable with tube removal. The current practice at MD Anderson Cancer Center is 400 mL or less over 24 hours. Readmission rates for pleural effusions requiring drainage remain low.

The amount of suction or when the suction is removed from the chest tube and placed on water seal is also variable by center. Two opposing philosophies exist. Applying suction helps to fully drain the chest cavity and allows the visceral and parietal pleurae to be in contact and theoretically seal the air leak. On the other side of the debate, applying suction keeps air moving through the hole or holes in the pleura, preventing healing. Hawley, Gunn, and Elliott (2014) conducted a systematic review that demonstrated chest tubes

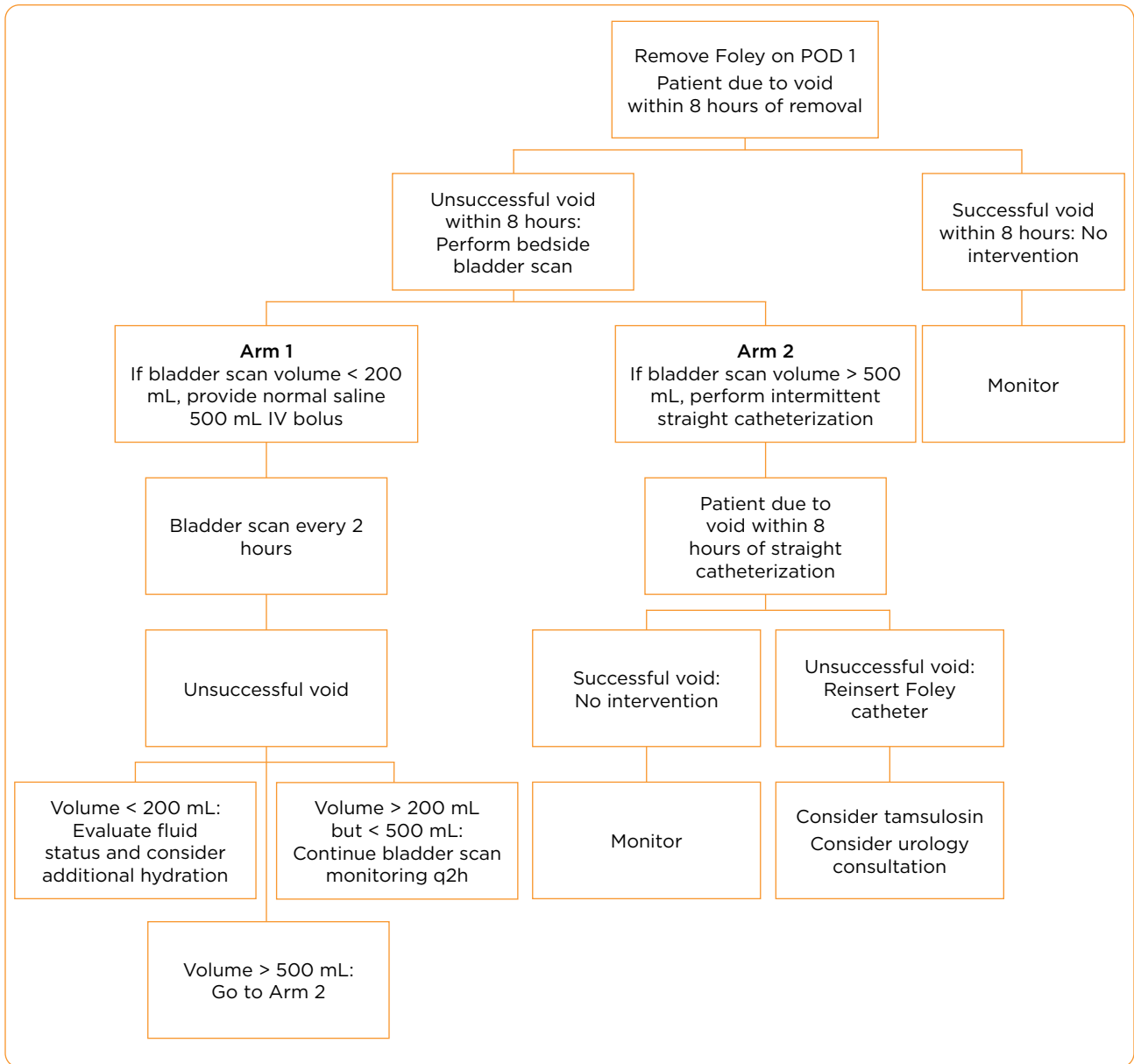


Figure 1. No-Foley protocol. POD = postoperative day.

being placed on water seal decreased the hospital length of stay as well as the number of days the chest tube remained in place (Hawley et al., 2014). The group at MD Anderson Cancer Center removes suction or decreases the suction to the lowest level possible to maintain expansion of the lung as soon as possible. This provides the patient with greater mobility and a feeling that they are making progress. Patients are sent to the radiology department on postoperative day one on water seal. If the lung remains expanded and they do not develop a large or growing amount of subcu-

taneous air, the tube is kept on water seal. Chest tubes that must remain on suction are reassessed daily to determine when the suction can safely be removed. Chest radiographs are kept to a minimum. A portable chest radiograph is performed upon arrival to the PACU, and a two-view chest radiograph is routinely performed on postoperative day one. Any additional radiographs are performed only due to a change in the patient’s status or a change in the chest tube management such as going from suction to water seal.

Postoperative Nausea and Vomiting Prophylaxis

Nausea and vomiting after surgery can be very distressing to patients and limit their mobility and general rehabilitation. Postoperative nausea and vomiting can also put patients at increased risk for aspiration. Retching can increase pain and place a fresh anastomosis at risk. The incidence of postoperative nausea is roughly 50% and vomiting is nearly 30%. The intraoperative anesthesia management and other patient risk factors have a direct impact on PONV. Even with optimal anesthesia management and drug prophylaxis, not all PONV can be eliminated. Pain management that focuses on reducing the use of opioids can play a significant role in decreasing the incidence of PONV (Gan et al., 2014). This strategy is incorporated into the practice at MD Anderson Cancer Center.

Other treatments include ondansetron 4 mg IV every 6 hours as needed as the first-line agent. In the PACU, inhalation of an isopropyl alcohol skin prep is utilized for quick relief. This has been shown to be beneficial and more cost-effective than standard drug treatment (Merritt, Okyere, & Jasinski, 2002). Patients with complaints of dizziness with ambulation or motion, or those who have already used ondansetron without relief, may have a scopolamine transdermal patch applied that can stay in place for 3 days. Additional antiemetics from other drug categories such as prochlorperazine maleate, metoclopramide, and promethazine may be prescribed on an as-needed basis. For patients with intractable PONV, the integrative medicine group may be consulted to provide acupuncture. Acupuncture has been shown to be an effective nonpharmacologic intervention for reducing nausea, vomiting, and the need for rescue antiemetics (Gan et al., 2014).

Multimodal Pain Relief

Adequate pain control after thoracic surgery is the cornerstone of ERATS and is essential to prevent significant morbidities. Poorly controlled pain means patients are not able to ambulate or partake in pulmonary toileting and thereby increase their risk for pulmonary complications, deconditioning, venous thromboembolic events, and ileus. Additionally, uncontrolled prolonged acute pain can result in chronic pain syndromes.

Pain can have many etiologies after chest surgery; therefore, a multimodal approach to treatment with a focus on avoiding opioids is utilized. Opioids may be necessary, but measures should be taken to reduce their use as they have a myriad of side effects. Common side effects include drowsiness, dry mouth, and constipation. More serious side effects include somnolence, confusion, and severe respiratory depression with hypercapnia that may require mechanical ventilation. In addition to pharmacologic interventions, there are several nonpharmacologic options to treat pain, such as massage and cold therapy. These interventions are supported by the clinical practice guideline, “Executive Summary: Clinical Practice Guidelines for the Prevention and Management of Pain, Agitation/Sedation, Delirium, Immobility, and Sleep Disruption in Adult Patients in the ICU,” published in *Critical Care Medicine* (Devlin et al., 2018).

The postoperative pain regimen at MD Anderson Cancer Center utilizes the medications described in the preoperative pain medication section listed in Table 1, along with several other medications that will be described and listed in Table 2. The routine use of liposomal bupivacaine has been pivotal in the success of the opioid-sparing strategy. The dosing used for acetaminophen is 1,000 mg IV every 6 hours for 24 hours and then changed to be given orally at the same dose. This dose will be continued throughout the hospital stay and for 10 days after discharge. Consideration is given to patients with baseline liver dysfunction. The dose is either decreased based on the severity of the liver dysfunction or eliminated completely.

Nonsteroidal anti-inflammatory drugs (NSAIDs) aid greatly in the reduction of inflammation postoperatively and may be responsible for controlling the shoulder pain that many patients who undergo lung surgery experience. The dosing for NSAIDs is ketorolac 15 mg IV every 6 hours for 48 hours and then changed to celecoxib 200 mg by mouth every 12 hours. Celecoxib is then continued throughout the hospital stay and in the outpatient setting for an additional 10 days. Caution is used for patients with baseline renal insufficiency or previous nephrectomy as well as those with a history of gastrointestinal ulcer history.

Nonsteroidal anti-inflammatory drugs are known for their potential gastrointestinal toxic-

Table 2. ERATS Postoperative Medications

Medication	Postoperative dosing	Discharge dosing
Acetaminophen	1,000 mg IV every 6 hours for 24 hours, then converted to 1,000 mg by mouth every 6 hours	1,000 mg by mouth every 6 hours for 10 days
Ketorolac	15 mg IV every 6 hours for 48 hours	-
Celecoxib	200 mg by mouth every 12 hours once ketorolac completed	200 mg by mouth every 12 hours for 10 days
Famotidine	40 mg by mouth every 12 hours	40 mg by mouth every 12 hours for 10 days
Gabapentin	300 mg by mouth every 8 hours	300 mg by mouth every 8 hours for 7 days, then 300 mg every 12 hours for 7 days, then daily for 7 days
Tramadol	50 mg by mouth every 6 hours as needed for mild pain	50 mg by mouth every 6 hours as needed for mild pain if utilized in the hospital
Hydromorphone	0.5 mg IV every 15 minutes as needed for moderate to severe pain for two doses; Consider PCA if pain persists	-

Note. PCA = patient-controlled analgesia.

ity. Famotidine at a dose of 40 mg by mouth every 12 hours is given along with any NSAID while in the hospital as well as upon discharge. Famotidine at this higher dose was chosen based on a Cochrane database review from 2002 that showed a high dose of an H₂-receptor antagonist reduced the risk of both gastric and duodenal ulcers in patients receiving NSAIDs (Tuskey & Peura, 2013). Famotidine is less expensive than proton pump inhibitors, has a good safety profile, and a low rate of drug-to-drug interactions.

Gabapentin is given as 300 mg by mouth every 8 hours. Dosing may be reduced for elderly patients or those experiencing side effects such as dizziness, instability with ambulation, or somnolence. Gabapentin is also continued upon discharge as a 3-week taper, every 8 hours for 1 week, then every 12 hours for 1 week, and then daily for 1 week. Tramadol is used on an as-needed basis at 50 mg by mouth every 6 hours as the first-line agent for breakthrough pain. Hydromorphone is the second-line agent. Dosing for hydromorphone is 0.5 mg IV every 15 minutes for three doses. If the pain is not controlled after the available doses have been utilized, the surgical team is notified, and a patient-controlled analgesia option may be ordered. Other pain relievers that are used as needed include methocarbamol, a muscle relaxant that is available IV and by mouth, and a lidocaine topical patch, which is a local anesthetic that targets a very specific area of pain.

Atrial Fibrillation Prophylaxis and Management

Postoperative atrial fibrillation (AF) occurs in approximately 4% to 37% of patients undergoing a lung resection procedure. The risk increases with the extent of lung resected (Garner et al., 2017). According to Roselli and colleagues (2005), there are additional factors that put some patients at higher risk than others. These factors include older age, male gender, paroxysmal AF, heart failure, clamshell incision, and right pneumonectomy (Roselli et al., 2005).

Postoperative atrial fibrillation can lead to increased morbidity, longer hospital stay, and increased costs. Although there is no standard pathway for prevention, there are steps that have been shown to decrease the incidence as described in the 2014 American Association for Thoracic Surgery Guidelines. Patients who routinely take beta blockers preoperatively are restarted on them as soon as clinically safe. Current practice is to restart an intravenous dose that is equivalent to the patient's home dose in the PACU with hold parameters for systolic blood pressure and heart rate. Once the patient is taking medications by mouth and has tolerated the IV dosing, the patient is transitioned to home oral dosing. Magnesium levels are monitored and low levels are supplemented with the administration of magnesium sulfate intravenously.

For those patients in whom atrial fibrillation could not be prevented, a standardized protocol for management is followed. Figure 2 provides details

of the protocol. The mainstay of this protocol is rate control with a beta blocker, metoprolol tartrate 5 mg IV every 5 minutes for three doses followed by 5 mg IV every 6 hours. If the rhythm fails to convert, then the addition of an amiodarone bolus of 150 mg IV is given followed by an infusion of 1 mg/hour for 8 hours and then decreased to 0.5 mg/hour for 16 hours. The patient is then converted to oral dosing of amiodarone and the infusion is discontinued. The patient is discharged with a 4-week taper of oral amiodarone. Should the patient remain in atrial fibrillation, a cardiology consult is considered and a CHA₂DS₂-VASc score is calculated to determine the need for anticoagulation.

ENHANCED RECOVERY PROGRAM OUTCOMES

Enhanced recovery after surgery was listed as number eight on Cleveland Clinic's list of top 10

medical innovations of 2018 (Cleveland Clinic, 2018). This comes as no surprise in an era of record hospital readmissions, increased Medicare costs, and the opioid epidemic. The ERATS protocol has come to be the standard of care for all patients undergoing an operation in the Department of Thoracic and Cardiovascular Surgery at MD Anderson Cancer Center. A study published in *The Annals of Thoracic Surgery* concluded that "ERAS was associated with improved postoperative outcomes, including decreased length of stay and pulmonary and cardiac morbidity after thoracotomy. ERATS safety was demonstrated by low rates of adverse events without effect on hospital readmission or perioperative deaths" (Van Haren et al., 2018). Madani and colleagues (2015) found similar outcomes with their enhanced recovery pathway after lung surgery, showing a decreased hospital length of stay, decreased num-

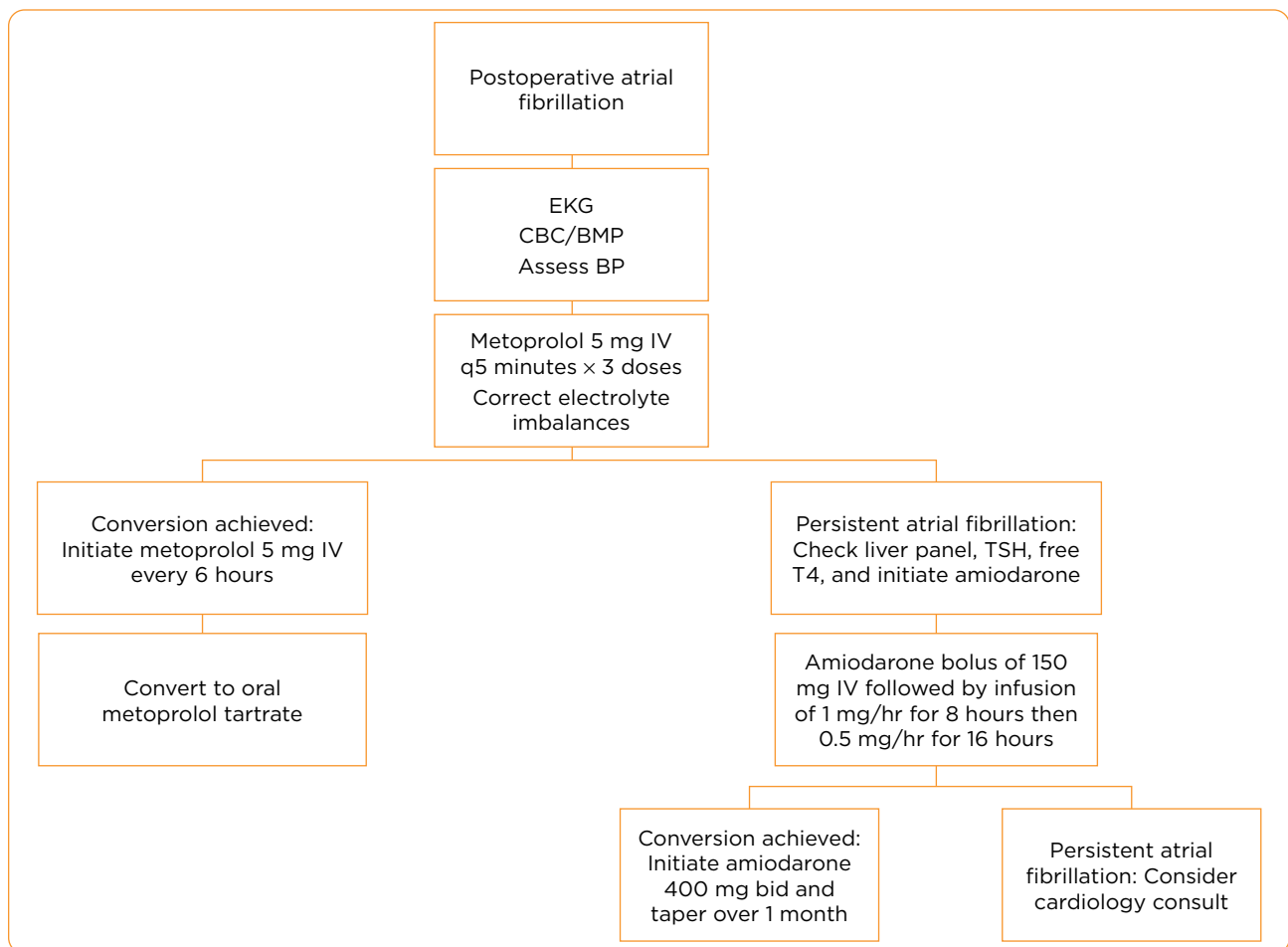


Figure 2. Atrial fibrillation management. EKG = electrocardiogram; CBC = complete blood count; BMP = basic metabolic panel; BP = blood pressure; TSH = thyroid stimulating hormone.

ber of days with chest tubes, and no increase in readmission or chest tube reinsertion rates. Postoperative compliance with ERAS strategies has been shown to have the greatest effect on overall

recovery, particularly open procedures (Aarts et al., 2018). Table 3 summaries the key components of ERATS that can be implemented to achieve these results.

Table 3. Enhanced Recovery After Thoracic Surgery (ERATS) Key Components and Process

Components	Phase of operative care	Process
Patient education	Every phase	<ul style="list-style-type: none"> • Verbal education • Written materials • Video presentations
Avoidance of fasting	Preoperative	<ul style="list-style-type: none"> • Clear liquid diet up until 2 hours before surgery
Carbohydrate loading	Preoperative	<ul style="list-style-type: none"> • 800 mL of 12.5% carbohydrate-containing drink night before surgery and 400 mL the morning of surgery
Multimodal analgesia	Every phase	<ul style="list-style-type: none"> • Refer to Table 1 • Acetaminophen • Celecoxib • Gabapentin • Tramadol
Opioid sparing	Intraoperative; postoperative	<ul style="list-style-type: none"> • Reserve opiates for breakthrough pain unmanaged by multimodal analgesia
Total intravenous anesthesia	Intraoperative	<ul style="list-style-type: none"> • Agents such as dexmedetomidine, propofol, and ketamine
Goal-directed fluid therapy	Intraoperative; postoperative	<ul style="list-style-type: none"> • Use of minimally/noninvasive hemodynamic tools • Avoid salt and fluid overload • Vasopressor support as needed
Postoperative nausea and vomiting preventive measures	Every phase	<ul style="list-style-type: none"> • Carbohydrate loading • Short-acting volatile anesthetics • Antiemetic medications • Dexamethasone • Scopolamine • Nonpharmacologic interventions
Liposomal bupivacaine	Intraoperative	<ul style="list-style-type: none"> • Dosage based on the size of surgical site • Injection performed by surgeon at the time of surgery
Early oral intake	Postoperative	<ul style="list-style-type: none"> • Clear liquid diet day of surgery • Diet advanced as tolerated postoperative day 1
Early mobilization	Postoperative	<ul style="list-style-type: none"> • Ambulation within 4 hours of admit to unit and minimum of 4 times daily thereafter
Venous thromboembolism prophylaxis	Intraoperative; postoperative	<ul style="list-style-type: none"> • Heparin 5,000 units subcutaneous every 8 hours
Antibiotic prophylaxis	Every phase	<ul style="list-style-type: none"> • Initiated 60 minutes before incision • Ampicillin/sulbactam or ciprofloxacin/vancomycin for penicillin allergy • Verified in intraoperative time out • Continued for 24 hours postoperatively
Chest physiotherapy	Postoperative	<ul style="list-style-type: none"> • Incentive spirometry • Oscillating positive expiratory pressure therapy • Albuterol and ipratropium
Avoidance of catheterization	Intraoperative; postoperative	<ul style="list-style-type: none"> • Refer to Figure 1
Chest tube management	Postoperative	<ul style="list-style-type: none"> • Minimize tubes • Minimize suction • Remove when meets criteria
Atrial fibrillation management	Postoperative	<ul style="list-style-type: none"> • Refer to Figure 2

SUMMARY

Enhanced recovery after surgery is not a novel concept. The adaptation for use in thoracic surgery, however, has been slower than in other specialties. Our experience with ERATS has been a positive one. Our group has seen ERATS use to be safe, cost-effective, and demonstrate significantly improved outcomes for our patients. Utilizing these guidelines in a collaborative effort with the anesthesia group and perioperative staff can yield a successful ERATS program. ●

Disclosure

The authors have no conflicts of interest to disclose.

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