Enhanced Recovery After Thoracic Surgery

Nathan Haywood, MD[a], Ian Nickel, MD[a], Aimee Zhang, MD[a], Matthew Byler, MD, MBA[a], Erik Scott, MD[a], Walker Julliard, MD[a], Randal S. Blank, MD, PhD[b], Linda W. Martin, MD, MPH[a,c,*]

KEYWORDS

• Thoracic surgery • Prehabilitation • Opioid sparing • Early ambulation • Early enteral nutrition

KEY POINTS

- Enhanced recovery pathways (ERPs), used across multiple surgical subspecialties, are multidisciplinary approaches to the delivery of perioperative care that are designed to return patients to baseline as quickly as possible.
- Although small variations exist between programs, core tenets of thoracic surgery ERP have been implemented in several centers over the last few years.
- Evidence of the benefit of thoracic ERP has started to emerge in terms of clinical outcomes and health care–associated cost.

INTRODUCTION

To lessen the physiologic and psychological stress of patients undergoing surgery, protocolized approaches using multidisciplinary delivery of care have been adopted. Coined enhanced recovery after surgery (ERAS), the goal includes returning patients to their preoperative baselines as early as possible. Enhanced recovery pathways (ERPs) were initially described in colorectal surgery more than 20 years ago and have since been implemented across multiple surgical subspecialties.[1] Protocols encompass the preoperative, intraoperative, and postoperative periods and have shown benefit in patient outcomes as well as health care–associated cost.[1] Although variations exist between institutions, consistent core tenets include preoperative patient education, avoidance of prolonged preoperative fasting, limiting intravenous fluid administration, multimodal opioid-sparing analgesia, and early ambulation.[2]

Surgical access for thoracic surgery requires one of the most painful incisions even when a minimally invasive approach is used.[3] In addition, lung surgery is associated with significant risks of postoperative morbidity.[4] As such, patients undergoing thoracic surgery encounter numerous psychological and physiologic stressors. In the past several years, ERPs have been developed in thoracic surgery (**Box 1**). Although similar in some aspects to earlier described fast-track thoracic surgery pathways, thoracic ERP places heavier focus on the quality rather than the speed of recovery, achievement of homeostasis, multidisciplinary delivery of care, preoperative education, and opioid-sparing pain management.[3] Evidence of the benefit of thoracic ERP has started to emerge.[5] However, implementation of such a program may seem daunting. This article presents common components of an ERP for thoracic surgery and discusses contemporary outcomes. Although ERPs for

[a] Division of Thoracic & Cardiovascular Surgery, Department of Surgery, University of Virginia Health System, 1215 Lee Street, Charlottesville, VA 22908-0679, USA; [b] Division of General Anesthesiology, Department of Anesthesiology, University of Virginia Health System, 1215 Lee Street, Charlottesville, VA 22908-0679, USA; [c] Thoracic Surgery, University of Virginia Health System, 1215 Lee Street, Charlottesville, VA 22908-0679, USA
* Corresponding author. Thoracic Surgery, University of Virginia Health System, 1215 Lee Street, Charlottesville, VA 22908-0679.
E-mail address: LM6YB@virginia.edu

Thorac Surg Clin 30 (2020) 259–267
https://doi.org/10.1016/j.thorsurg.2020.04.005

Box 1
ERAS Society and European Society of Thoracic Surgeons guidelines for enhanced recovery after lung surgery

Preoperative phase
- Preadmission information, education, counseling
- Preoperative nutrition screening and counseling
- Smoking cessation
- Alcohol dependency management
- Anemia identified, investigated, corrected
- Prehabilitation, pulmonary rehabilitation

Perioperative phase
- Clear fluids until 2 hours before; oral carbohydrate load
- Venous thromboembolism prophylaxis
- Antibiotic prophylaxis and skin preparation
- Prevent intraoperative hypothermia
- Anesthesia: lung-protective strategies; use regional and general anesthesia together
- Postoperative nausea and vomiting control
- Regional anesthesia and pain relief: multimodal opioid sparing
- Fluid management: discontinue intravenous fluids as soon as possible and replace with oral fluids
- Atrial fibrillation prevention strategy should be in place
- Surgical technique: muscle sparing if thoracotomy needed, video-assisted thoracoscopic surgery for early stage when possible

Postoperative phase
- Chest tubes: avoid external suction, remove as soon as possible, use single tube
- Urinary drainage: avoid if possible, reasonable to use if epidural, spinal
- Early mobilization and physical therapy within 24 hours

Adapted from Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, et al. Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS®) Society and the European Society of Thoracic Surgeons (ESTS). Eur J Cardiothorac Surg. 2019;55(1):93–4; with permission.

esophageal surgery have also emerged, the focus here is on lung surgery. Common trends are discussed, as well as our institutional experience.

PREOPERATIVE PHASE

Preadmission Education and Information

ERPs place heavy emphasis on the intraoperative and postoperative care of thoracic surgical patients. However, preoperative optimization and preparation are equally important for truly enhanced recovery (ER). The provision of tailored information to the patients about the procedure and recovery process has proved to be fundamental to the optimization process.[6] Delivery should be multimodal with a combination of personal counseling, printed materials, and/or electronic resources designed to enhance patient understanding. It is our practice to provide patients with a preassembled folder during a preoperative clinic visit. This material serves to achieve the following goals: (1) to prepare and manage patient expectations for the preoperative, intraoperative, and postoperative phases; (2) to encourage active participation of the patients in their care; and (3) to alleviate patient anxiety about the accelerated pace of recovery and the unknown.

Smoking Cessation

Smoking has obvious long-term risks and also represents a considerable source of short-term risk for postoperative complications in thoracic surgery.[7] The provision of resources for smoking cessation is essential for patients who need thoracic surgery. The current recommendations suggest intervention initiated at least 4 to 8 weeks before surgery, but, in general, smoking cessation should be recommended regardless of timing.[8]

Exercise Capacity and Prehabilitation

Preoperative optimization of functional status and physical reserve has been advocated to better allow patients to withstand the stress of the perioperative period and return to normal activity (**Fig. 1**).[9] Coined prehabilitation, the goal is to increase preoperative functional level with exercise training and nutritional supplementation.[9] Thoracic ERPs have adapted prehabilitation because poor preoperative exercise capacity in patients undergoing lung surgery has been associated with increased postoperative complications and increased length of stay (LOS).[1] Although many programs incorporate some form of exercise prehabilitation, outcome improvements following lung cancer surgery have yet to be established. During the preoperative visit at our institution, patients are given information about preoperative exercise and are encouraged to be as active as possible leading up to surgery.

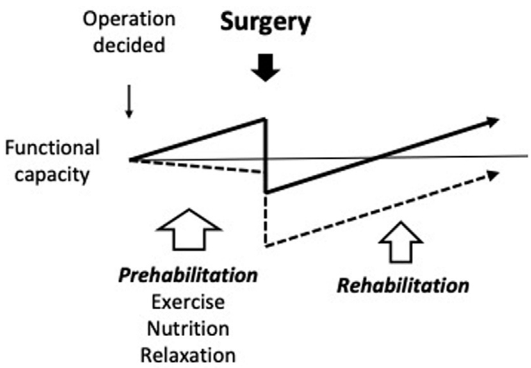

Fig. 1. Theoretic model showing the benefit of prehabilitation on functional capacity before and after surgery. (*From* Kawaguchi M, Ida M, Naito Y. The role of Perioperative Surgical Home on health and longevity in society: importance of the surgical prehabilitation program. J Anesth. 2017;31(3):319–24; with permission.)

Nutrition and Carbohydrate Loading

Essential principles of the preoperative ERP include nutritional optimization and avoidance of long-term fasting.[10] European Society for Clinical Nutrition and Metabolism guidelines recommend screening patients preoperatively in an effort to identify malnutrition (weight loss >10%–15% within 6 months; body mass index <18.5; serum albumin level <3 g/dL) and, if indicated, provide nutritional support for 10 to 14 days before major surgery.[10] Fasting beginning at midnight before the operation is no longer recommended and can lead to dehydration and insulin resistance, which is exacerbated by the metabolic stress associated with surgery.[11–13] Compared with a traditional fasting period, a Cochrane Review in the early 2000s showed no increased aspiration risk with oral fluids 2 to 3 hours before surgery.[12,13] Preoperative oral carbohydrate loading 2 hours before surgery, initially in the laparoscopic cholecystectomy population, was found to mitigate postoperative nausea, vomiting, and pain, and to decrease overall LOS.[11,12] Pachella and colleagues[14] (2019) showed that carbohydrate loading 2 hours before thoracic surgery decreased use of opioids and antiemetic medications in the immediate postoperative period. There are numerous ERAS drinks available but no specific ones have been shown to improve outcomes. Our institution uses regular 591-mL (20-oz) Gatorade because of low cost and availability.

INTRAOPERATIVE PHASE

Preemptive Analgesia and Regional Nerve Blockade

The authors routinely give oral acetaminophen, gabapentin, and celecoxib on arrival to surgical preparation area. We do not use celecoxib with renal insufficiency or planned pleurodesis. Regional nerve blockade is preferred to the use of opioids for preemptive pain control.[15] Thoracic epidural analgesia has been used for thoracotomy in thoracic ERPs[1,16,17]; however, it is associated with increased rate of postoperative hypotension, urinary retention, and weakness. Such complications are not congruent with the early mobilization goal of ERP.[1,17] Alternative strategies with fewer side effects include paravertebral and intercostal nerve blockade.[18,19] Elastomeric catheters containing local anesthetics are expensive, prone to occlusion, and have conflicting reports regarding efficacy in controlling postthoracotomy pain.[15,18,20] Liposomal bupivacaine (Exparel, Pacira Pharmaceuticals, Parsippany, NJ) has been used for regional nerve blockade in thoracic surgery.[15,21] This formula provides up to 96 hours of bupivacaine release from liposomal vesicles, obviating continuous infusion catheters.[15] Following lung resection, Rice and colleagues[15] (2015) showed similar pain scores and decreased LOS in patients undergoing intercostal nerve blockade with liposomal bupivacaine compared with thoracic epidural anesthesia. Similar findings have been previously reported.[19] At our institution, preemptive regional nerve blockade includes posterior intercostal nerve blockade of interspaces 3 to 10 using dilute liposomal bupivacaine injected transcutaneously, at the start of the operation.[22] We have found the best results when done with video-assisted thoracoscopic surgery (VATS) guidance, regardless of plans for VATS or open surgery. Postoperative analgesia is further augmented with the intrathecal administration of preservative-free morphine for patients requiring thoracotomy incisions and anatomic lung resections.

Deep Vein Thrombosis Prophylaxis, Skin Preparation, and Antibiotic Prophylaxis

All patients in thoracic ERP should have mechanical deep vein thrombosis (DVT) prophylaxis with sequential compression devices or foot pumps.[16] Pharmacologic DVT prophylaxis (low-molecular-weight heparin or unfractionated heparin) should be administered in patients not at high risk of bleeding.[16] Preoperative intravenous antibiotic prophylaxis, usually a cephalosporin, should be administered no more than 60 minutes before incision and redosed appropriately intraoperatively.[16] Extended antibiotic prophylaxis following surgery has not been shown to improve outcomes.[16] Hair removal should be as limited as possible.[16] Chlorhexidine-alcohol solutions are preferred, because they have been shown to decrease surgical site infection compared with povidone-iodine solutions.[16,23]

Intraoperative Anesthesia

Short-acting anesthetic agents permitting early extubation are a mainstay of thoracic ERPs.[1,16,17,24] Compared with intravenous anesthesia, volatile inhaled anesthetic agents such as sevoflurane and desflurane have been shown to suppress the local alveolar inflammatory response associated with one-lung ventilation.[25] However, total intravenous anesthesia with propofol has been associated with lower rates of postoperative nausea and vomiting.[26] As such, acceptable anesthetic includes short-acting volatile or intravenous anesthetics used individually or in combination.[16]

Intraoperative multimodal analgesia with minimal use of opiates is a core component of ERPs. Intraoperative ketamine is used as part of our thoracic ERP program.[3] Although its specific benefit in thoracic surgery has not yet been clearly elucidated, ketamine combined with regional anesthesia has been shown to control perioperative pain in major digestive surgery.[27] The strategy at our institution includes induction with appropriate anesthetic and adjunctive agents followed by maintenance anesthesia with sevoflurane and ketamine.[3] Opiate use is minimized and only administered with approval by an attending physician.[3]

Intraoperative Fluid Management

Perioperative fluid management in thoracic surgery is of critical importance because liberal use can increase risk of pulmonary complications such as acute respiratory distress syndrome. There is also concern that excessive volume restricting can lead to hypovolemic complications such as acute kidney injury.[1,16,17,24] In a retrospective analysis of 1442 patients undergoing thoracic surgery, Ahn and colleagues[28] (2016) showed that fluid-restrictive approaches (<3 mL/kg/h) were not associated with increased development of acute kidney injury. At present, most thoracic ER programs use intraoperative balanced crystalloid in a restrictive manor (<3 mL/kg/h, <2 L total intraoperatively).[3,24]

Intraoperative Ventilation

Perhaps in no other population is it more important to limit ventilator-associated pulmonary complications than in those undergoing thoracic surgery. For this reason, a focus of thoracic ER programs is a lung-protective ventilation strategy.[1,16,17,24] Because one-lung ventilation is typically required for optimal surgical exposure in lung surgery, lung-protective strategies have focused on limiting tidal volumes and airway driving pressure in the ventilated lung and preventing hypoxia and other complications associated with collapse in the nonventilated lung.[16,24] Current strategies include limiting tidal volume to 4 to 5 mL/kg predicted body weight in the ventilated lung with positive end-expiratory pressure to limit hypoxia.[16,24] In addition, low-level continuous positive airway pressure to the collapsed lung has been shown to decrease inflammatory response associated with complete collapse.[29]

POSTOPERATIVE PHASE

Postoperative Analgesia

Effective postoperative pain management is a prerequisite for adequate pulmonary mechanical function and hygiene, and preventing postoperative atelectasis, pneumonia, and other complications. The authors use a ketamine infusion (0.1–0.5 mg/kg) for 24 to 48 hours following surgery.[30] At this dose, ketamine augments postoperative pain control without causing adverse hemodynamic effects or respiratory depression.[31] Occasionally patients experience mild hallucinations or diplopia, which is usually well tolerated and resolves with discontinuation of the infusion. With the use of these adjuncts as well as scheduled oral analgesics (acetaminophen, gabapentin, and nonsteroidal antiinflammatory drugs), opioids can be reserved to treat breakthrough pain.[1,3]

Bladder Drainage

Urinary catheter removal on the first postoperative day should occur even in the presence of a thoracic epidural or spinal morphine to avoid infection and to optimize patient comfort.[32] This technique is often used with bladder scan urinary retention protocols and, in our program, the routine administration of tamsulosin for all male patients older than 50 years.[3,33] The successful implementation of early, protocol-driven removal of indwelling urinary catheters as part of ERPs decreases LOS.[30,33]

Postoperative Diet

ERPs across specialties share the goal of maintaining homeostasis to avoid catabolism, protein loss, and cellular dysfunction.[34] Early discontinuation of intravenous fluids and initiation of oral feeding after surgery are important elements of this strategy. Thoracic ERPs permit diet advancement as tolerated within an hour or two of surgery. ERPs typically include a multimodal approach to prevent postoperative nausea and vomiting by both nonpharmacologic (preoperative carbohydrate loading, avoidance of crystalloid overload) and pharmacologic (avoidance of opiates, regular administration of antiemetics, intraoperative dexamethasone 4 mg) measures, as well as aggressive inpatient and discharge oral bowel regimens.[3,35]

Chest Tube Management

Chest tubes are a necessary evil of thoracic surgery because they impair mobilization and increase LOS and cost.[1,36] The application of external suction may also exacerbate air leak duration[37] and further limit mobilization by anchoring the patient to the suction source.[5] Removal of chest tubes objectively improves ventilatory function, as measured by expiratory volume and vital capacity, and reduces chest pain after forced thoracic surgery.[38] Historically, chest tube management was based on surgeon experience and preference, with most surgeons preferring to leave the chest tube in place until the volume of drainage decreased below an arbitrary threshold (often 250 mL/d or less).[39] More aggressive chest tube removal strategies have shown similar outcomes with fluid thresholds of 450 to 500 mL/d following VATS and thoracotomy.[40,41] For our institutional ERP, chest tubes are placed on water seal within 12 hours, unless there is a major air leak. Chest tubes are removed when there is no air leak, bloody output, or chyle. The total volume of chest tube output and postoperative days since surgery are not factors in the decision.[3]

Postoperative Atrial Fibrillation

Postoperative atrial fibrillation (POAF) is the most common arrhythmia after thoracic surgery.[42] It has been associated with increased mortality, increased hospital and intensive care unit LOS, and higher resource use.[36,42,43] American Association for Thoracic Surgery (AATS) guidelines on the prevention of POAF include a class I recommendation for continuing the patient's home β-adrenergic antagonists and a class IIb recommendation for repleting low serum magnesium levels. In addition, intravenous amiodarone or diltiazem administration for POAF prophylaxis is given a class IIa recommendation.[44] Three meta-analyses have been performed on the topic of medical prophylaxis for POAF after general thoracic surgery, all of which show that calcium channel blockers (CCBs; eg, diltiazem), amiodarone, β-blockers, and magnesium replacement are all effective agents for prevention of POAF.[45–47]

In 2017, Zhao and colleagues[45] performed a meta-analysis that evaluated 22 studies that compared pharmacoprophylaxis for prevention of POAF. In addition to confirming the aforementioned recommendations, they also showed that prophylaxis with β-adrenergic antagonists was well tolerated and may be more effective than CCBs or amiodarone. β-Adrenergic antagonists were not included in the 2014 AATS guidelines for prevention of POAF; however, in 2016, a prospective randomized controlled trial by Cardinale and colleagues[48] showed metoprolol to be effective in reducing incidence of POAF. Our practice is to resume home β-adrenergic antagonist therapy. Other patients are stratified to either high-risk or low-risk groups, with high-risk (defined as age >50 years having either thoracotomy or anatomic resection) patients receiving postoperative diltiazem for prevention of POAF.

OUTCOMES

Patient Outcomes

Although a predecessor of contemporary thoracic ERP, fast-tracking for pulmonary resection was described by Cerfolio and colleagues[49] as early as 2001. An assessment of patient outcomes following a fast-track clinical pathway for lung resection was described in 2008.[50] In a prospective randomized trial, Muehling and colleagues[50] reported decreased pulmonary complications associated with a fast-track pathway for lung resection. Overall morbidity and mortality were unchanged.[50] Madani and colleagues[33] (2015) later showed a decreased postoperative complication rate without change in early mortality in an ERP for open lobectomy. Similar findings were shown by Paci and colleagues[51] (2017) for elective lung resection, including both VATS and thoracotomy. When VATS lobectomy was evaluated independently, Brunelli and colleagues[52] (2017) showed no difference in postoperative complications or early mortality associated with implementation of an ERP. Most of these pathways used conservative chest tube management, epidural pain control, and patient-controlled anesthesia,[50] emphasizing that the components of published ERPs vary widely and, not surprisingly, the impact on outcomes varies as well.[3,21] In one of the largest published studies on ERP in lung cancer resection, Van Haren and colleagues[4] (2018) showed improved cardiac and pulmonary complication rates following thoracotomy.[4] However, a similar benefit was not shown in the minimally invasive cohort. Evidence is emerging that thoracic ERPs decrease complication rate following thoracotomy, but a similar benefit in VATS has not been consistently shown, perhaps because there is less room for improvement. The authors recently published a comparison of VATS and open lobectomies on an ERP, which suggests the ERP negates differences between VATS and open lobectomy for traditional surgical outcomes, including rate of postoperative complications. Because more total nodes and nodal stations were assessed with thoracotomy, this factor may have important oncologic implications.[53] Rogers and colleagues[35] (2018) showed a positive association between compliance with major ERP core tenets and decreased morbidity following lung cancer resection. It is unclear at this time whether the benefit stems from specific components of thoracic ERP or all changes in aggregate.[5] Detailed study of patient outcomes related to ERP components and compliance will be critical for improvement as these programs continue to evolve.

Patient-Reported Outcomes and Length of Stay

Patient-reported outcomes (PROs) are measures of patient physical and psychosocial well-being that are directly reported by patients.[54] These metrics are increasingly used for quality of care.[54,55] A recent review of thoracic ERP by Medbery and colleagues[54] (2019) highlights the critical need to include PROs alongside traditionally reported measures of morbidity and mortality.

An important determinant in patient satisfaction is LOS. Grigor and colleagues[55] (2017) showed that prolonged LOS following lung cancer surgery was associated with a marked decreased in patient experience. Following implementation of a thoracic ERP protocol following thoracotomy, several centers have shown a decrease in postoperative LOS without increasing the readmission rate.[3,4,30,33,35] Madani and colleagues[33] (2015) showed a decrease in median LOS from 7 to 6 days in open lobectomy following ER protocol implementation. Other centers have since shown even greater benefit by focusing on early chest tube removal and avoidance of epidural use.[35] For example, 1-year analysis at our institution revealed a decrease in median LOS from 6 to 4 days following implementation of ERP for thoracotomy.[3] Similar findings have not yet been shown for all ERPs following VATS, perhaps because LOS is already short in this cohort, but some investigators have shown improvements even in a VATS cohort.[3,52,56,57] Decreased LOS not only leads to patient satisfaction but also translates into decreased resource use and health care–associated costs.

Return to Intended Oncologic Therapy

Cancer surgery is frequently just 1 part of multidisciplinary oncologic care. Full recovery after surgery is a key factor in receiving all prescribed cancer treatment and has been shown to improve disease-free and overall survival.[58] Standard of care in the treatment of stage II and higher non–small cell lung cancer includes adjuvant chemotherapy.[59] Achievement of good performance status (Eastern Cooperative Oncology Group 0) is generally required before initiation of chemotherapy. The decrease in postoperative morbidity, lower pain scores, and quicker return to baseline associated with thoracic ERPs positively affects the ability of patients to initiate and complete this critical component of care.[59] Nelson and colleagues[59] (2019) showed shortened time to adjuvant chemotherapy and higher rate of completing 4 or more chemotherapy cycles following adoption of a thoracic ERP. Impact on survival has not yet been reported in a lung cancer population.

Cost

Like other surgical disciplines, the adoption of thoracic ERP seems to be associated with a durable decrease in overall health system cost. The development of ERPs across multiple surgical disciplines and service lines has led to a decrease in hospital cost.[34,51] ERPs within thoracic surgery are no exception.[51,60,61] Although predating the current ERP era, standardized clinical care pathways reduced hospital costs following anatomic lung resections as early as 1997.[60–62] A Johns Hopkins University study reported hospital savings of approximately $4000 with the implementation of a standardized pathway following major pulmonary anatomic resection.[61,63] Similarly, decreased costs were shown using standardized pathways following VATS pulmonary resection the early 2000s.[60,63] Following the implementation of thoracic ERP protocol and ERPs, both VATS and thoracotomy remain associated with lower hospital costs. Mean inflation-adjusted hospital costs significantly decreased by about $5500 for VATS and almost $16,000 for major thoracotomy 1 year after the implementation of thoracic ERP at our institution.[3] Another study, by Paci and colleagues[51] (2017), showed no change in total institutional or health system costs following implementation of thoracic ERP, but it did show a reduction in societal cost by almost $4500 (Canadian). This finding is likely caused by quicker return to baseline and less productivity loss after discharge. In addition, although total institutional costs were unchanged, intensive care unit and ward costs were significantly lower following implementation, in part because of shorter hospital LOS.[51]

SUMMARY

Numerous studies have shown the clinical and economic benefits of ERPs for lung surgery. Areas of interest and ongoing study in thoracic ERP include the potential effect of opioid-sparing analgesia on chronic postthoracotomy pain, new opioid dependence, cancer recurrence, and the effect of ERP on PROs and quality-of-life measures. Continued multidisciplinary review and protocol revision are of paramount importance for ERP improvement. It is likely that the full potential of thoracic ERPs has not yet been realized and that more widespread adoption and study of these pathways will lead to further improvements in care and outcomes.

DISCLOSURE

The authors have nothing to disclose.

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