JOURNAL of ANESTHESIA and PERIOPERATIVE MEDICINE

Review Article

Enhanced Recovery After Surgery (ERAS) Protocols and Perioperative Lung Protection

Jeffrey Huang

From Anesthesiologists of Greater Orlando, Winter Park, Florida, USA.

Correspondence to Dr. Jeffrey Huang at jeffhuangmd@gmail.com.

Citation: **Jeffrey Huang. Enhanced recovery after surgery (ERAS) protocols and perioperative lung protection. *J Anesth Perioper Med* 2014; 1: 50-56.**

ABSTRACT

Aim of review: Patients are at risk for lung injury in the perioperative period. The enhanced recovery after surgery (ERAS) has been associated with a reduction in duration of hospital stay, readmissions, and reoperations, together with decreased mortality and morbidity, improved pain control, better cost containment, and improved patient satisfaction.

Method: we review the recent literatures on ERAS for prevention of perioperative pulmonary complications (PPCs).

Recent findings: Current ERAS protocols include >20 elements. Many elements in ERAS protocol can prevent perioperative lung injury, therefore reduce complications, enhance recovery, reduce length of stay, and lower the cost. Preadmission information, education and counseling, preoperative optimization, prophylaxis against thromboembolism, standard anesthetic protocol, laparoscopy and modifications of surgical access, perioperative fluid management, postoperative analgesia, and early mobilization impact directly on perioperative lung protection. Minimization of preoperative fasting, early resumption of oral intake, avoidance of bowel preparation can reduce the volume of intravenous fluid requirement, indirectly prevent lung injury.

Summary: ERAS elements can prevent lung injury, reduce complications, enhance recovery, reduce length of stay, and lower the cost.

Enhanced Recovery After Surgery (ERAS) is a standardard, coordinated interdisciplinary perioperative surgical care program that incorporates evidence- based interventions to minimize surgical stress, improve physiological and functional recovery, reduce complications, and facilitate earlier discharge from the hospital (1). ERAS has been associated with a reduction in duration of hospital stay, readmissions, and reoperations, together with decreased mortality and morbidity, improved pain control, better cost containment, and improved patient satisfaction (2-5). ERAS can achieve result on three dimensions of the Triple Aim: better health care, better patient experience, and lower cost. Therefore ERAS should be widely applied to optimize the quality and effectiveness of health care. Since the early 1990s, the ERAS has gradually evolved to become the standard of care in colorectal surgery (6). The benefits of ERAS have been also demonstrated in patients undergoing urological, gyne-

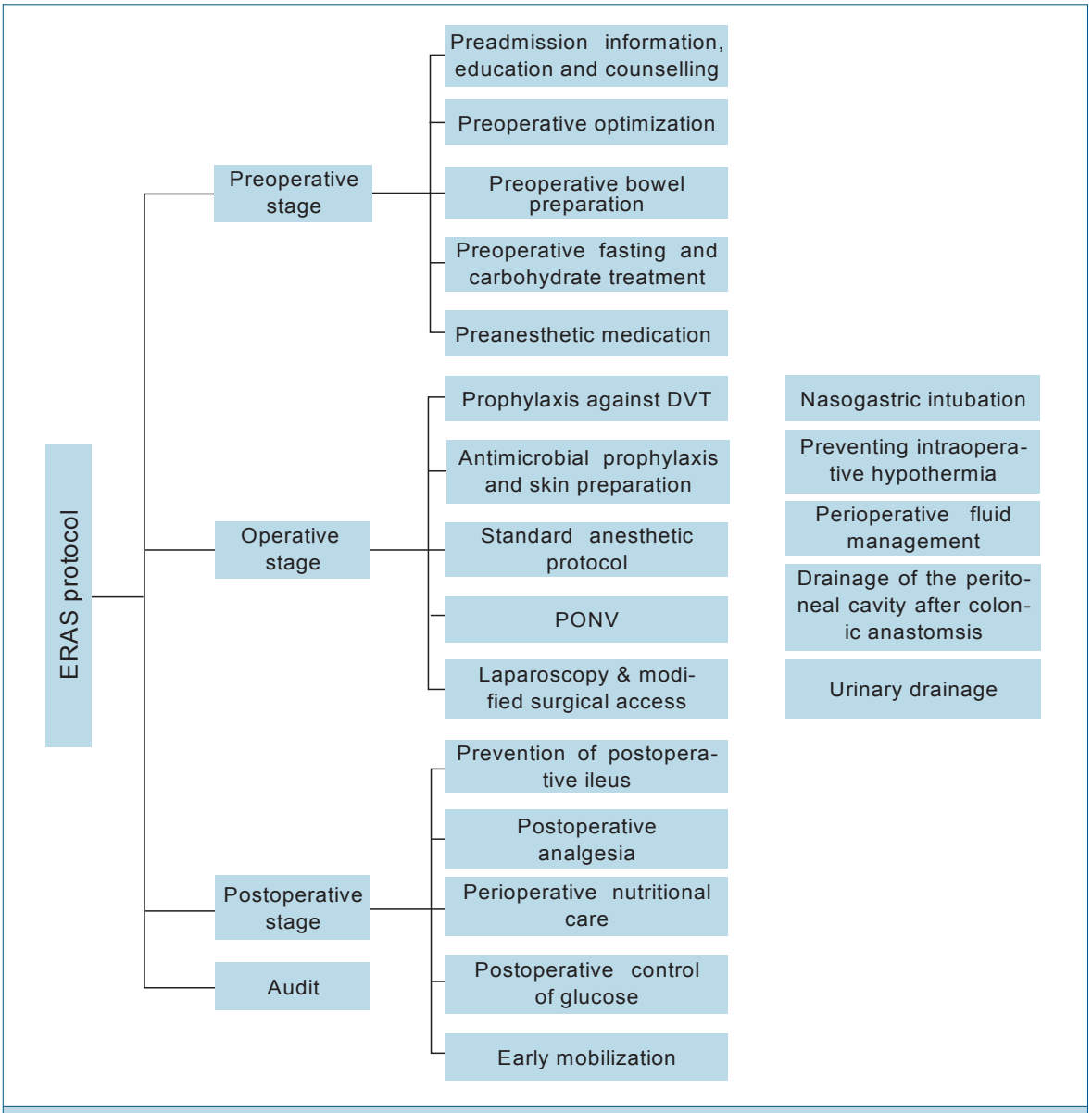

Figure. ERAS Elements.

cological, orthopedic, upper gastrointestinal, hepatobiliary, cardiac and vascular surgery.

Current ERAS protocols include >20 elements (Figure).

Patients are at risk for several types of lung injury in the perioperative period including atelectasis, pneumonia, pneumothorax, acute lung injury, and acute respiratory distress syndrome (7). Therefore, normal lungs need protection from multiple potentially injurious factors, including, but not limited to, cardiopulmonary bypass (CPB), sepsis, trauma, lung ischemia – reperfusion, and blood product transfusion (7). Injured lungs need protection from ongoing injury.

Many elements in ERAS protocol can prevent perioperative lung injury, or influence the extent and course of perioperative lung injury. These elements are reviewed and discussed as follows.

Preadmission Information, Education and Counseling

Personal counseling, leaflets or multimedia information containing explanations of the procedure along with tasks that the patient should be encouraged to fulfill may improve perioperative feeding,

early postoperative mobilization, pain control, and respiratory physiotherapy; and hence reduce the prevalence of complications (8-10).

Patient education in lung maneuvers initiated preoperatively is more effective in reducing pulmonary complications versus education initiated postoperatively (11,12). Lung expansion maneuvers include incentive spirometry and chest physical therapy consisting of various combinations of the following: deep breathing exercises, postural drainage, percussion and vibration, cough, suctioning, and mobilization (13). Therefore, preoperative education can improve pulmonary function, then reduce postoperative pulmonary complications.

Preoperative Optimization

Patients with pre-existing organ dysfunction [ischemic heart disease, chronic obstructive pulmonary disease (COPD) and renal insufficiency] are more likely to develop an acute coronary syndrome, heart failure, bronchopneumonia or respiratory failure following major interventions (14). Exacerbation of bronchial inflammation with airway instrumentation, preoperative bacterial airway colonization, surgery- induced immunosuppression and increased muscular work of breathing may all promote the onset of lung injury [postoperative pulmonary complications (PPCs)] (15).

PPCs may be manifested as mild hypoventilation or as fulminate pulmonary edema due to adult respiratory distress syndrome. It is true that pulmonary diseases affect oxygen uptake, carbon dioxide removal, and cardiac output (16). A recent review discussed patient- related risk factors that may lead to risk for PPCs (17). Important patient- related risk factors include smoking, poor general health, age 70 years or older, and COPD (17).

Use of bronchodilators and glucocorticoid agents, and cessation of smoking are principal treatments to optimize COPD patients. Preoperative inhaled beta-2 adrenergic agonists (i.e., salbutamol) and anticholinergic agents (i.e., ipratropium) should be continued up to the day of surgery in all symptomatic asthmatics and in COPD patients with bronchial hyperreactivity (18). Short- term treatment with systemic or inhaled corticosteroids has been shown to "tune up" the lung function and to decrease the incidence of wheezing following endotracheal intubation without increasing the risk of infection or wound dehiscence (18). Antibiotics should be prescribed only if there is evidence of pulmonary infection. Optimization of COPD patients reduced PPCs.

Smoking is another patient factor that has a negative influence on recovery. Current smokers have an increased risk for postoperative pulmonary and wound complications (19). Cigarette-smoke contains more than 1,000 components with wide-ranging effects on pulmonary, cardiovascular and immune functions, healing of wounds, homeostasis, drug metabolism and patient mental status, all of which may influence the postoperative outcome (20,21). Smoking status is a consistent univariate risk factor for adverse cardiac events and a variety of pulmonary adverse events such as bronchospasm, laryngospasm, cough and hypoxemia requiring intensive care unit (ICU) admission (15). Hence it is recommended that clinicians should advise complete cessation of smoking for at least 4 weeks before major elective surgery. Cessation of smoking can reduce incidence of lung injury.

Patients with well- controlled asthmatic disease present similar risk for PPCs as those patients without asthma, regardless of the type of anesthesia (22). The keys to an uncomplicated perioperative course are assiduous attention to detail in preoperative assessment, and maintenance of the anti-inflammatory and bronchodilatory regimens through the perioperative period. Potential trigger agents should be identified and avoided (23).

Sleep apnea may predispose to increased rate of PPCs. Preoperative recognition of obstructive sleep apnea (OSA), constant control of the airway, titration of analgesic and sedative drugs, and careful monitoring could avoid many unexpected complications after surgery (24).

Ventilation- associated pneumonia (VAP) is one of the most important risk factors for hospital mortality in cardiac surgery patients (25). Oronasopharyngeal decontamination with chlorhexidine has proven to be an effective method to reduce the VAP rate in these patients (26) and should be a routine practice (27).

Alcohol abusers have a two- to- threefold in-

crease in postoperative morbidity, the most frequent complications being bleeding, wound and cardiopulmonary complications (10). Experimental data indicate that ethanol causes depletion of pulmonary antioxidant glutathione which in turn leads to decreased surfactant production, impaired alveolar liquid clearance and alterations in epithelial cell permeability (28). One month of preoperative abstinence reduces postoperative morbidity by improving pulmonary and other organ function (29,30).

Low preoperative hemoglobin (Hb) levels are well known as major predicting factors in requiring perioperative blood transfusion in orthopedic surgery (31,32). Transfusion- related acute lung injury (TRALI) is defined clinically as the development of acute lung injury (ALI) during or within 6 hours after the transfusion of any blood product (33,34). TRALI has been the leading cause of transfusion- related mortality for many years (35).

A recent study (36) showed that preoperative iron deficiency (ID) was treated with iron and erythropoiesis-stimulating agent (ESA). Substituted anemic patients showed a distinctly higher preoperative and postoperative hemoglobin levels. Red blood cell (RBC) units requirement were reduced by 44% (36). Preoperative optimization of hemoglobin level can reduce transfusion requirement, and prevent acute lung injury.

Preoperative medical optimization (COPD, asthma, sleep apnea), cessation of smoking, abstinence alcohol, anemia correction can reduce PPCs.

Prophylaxis Against Thromboembolism

Deep Vein Thrombosis (DVT), with the associated risk of pulmonary embolism (PE), occurs in 45 to 75 % of patients who undergo orthopedic procedures on lower extremities (37). PE can result in serious lung injury.

The incidence of asymptomatic DVT in colorectal surgical patients without thromboprophylaxis is 30%, with fatal pulmonary embolus (PE) occurring in 1% of subjects (10). Patients with malignant disease, previous pelvic surgery, taking corticosteroids preoperatively, extensive comorbidity and hypercoagulable states are at increased risk (38, 10). Mechanical thromboprophylaxis with well- fitted compression stockings significantly reduced the prevalence of DVT in-hospitalized patients (39).

The addition of intermittent pneumatic compression should also be considered, particularly in patients with malignant disease or who have undergone pelvic surgery (40, 10). There is extensive evidence supporting the use of pharmacological thromboprophylaxis with low-molecular- weight- heparin (LMWH) or unfractionated heparin (10). A recent study of 4195 colorectal patients demonstrated that pharmacological prophylaxis reduced the prevalence of symptomatic venous thromboembolism (VTE) from 1.8% to 1.1% and also reduced overall colorectal cancer mortality (41,10). Therefore, prophylaxis against thromboembolism can prevent pulmonary embolism.

Standard Anesthetic Protocol

The anesthesiologist is responsible for three key elements in affecting outcome after surgery: stress reactions to the surgery, fluid therapy, and analgesia. Recognition of the importance of these ERAS components has led to the description of a "trimodal approach" for optimizing outcomes in laparoscopic surgery for anesthesiologists (42,10).

Mechanical ventilation is frequently requirement in patients under general anesthesia for surgery. Ventilation can cause so called ventilator-associated lung injury via overdistension of alveoli in aerated lung tissue, or repetitive opening and closing of atelectatic lung parts, or both (7).

Two meta- analyses of observational studies and randomized controlled trials of intra-operative ventilation concluded that lung- protective ventilation with lower tidal volumes and/or higher levels of positive end expiratory pressure (PEEP) could prevent ventilator- associated lung injury and postoperative complications (43, 44). Two randomized controlled trials support this by demonstrating that the combined use of lower tidal volumes and higher levels of PEEP protects against PPCs (45, 46).

One randomized controlled trial (47) and a recent meta-analysis (43) support lower tidal volume to be beneficial also in patients without acute respiratory distress syndrome (ARDS). Several smaller studies and trials (45,46) and two re-

cent meta-analyses (43, 44) support that protective ventilation is also beneficial in short-term ventilation for patients during general surgery.

Laparoscopy and Modifications of Surgical Access

Laparoscopy in colonic resection improves recovery if judged by the prevalence of postoperative complications, pain and hospital stay (10).

During laparoscopy surgery, the use of the steep Trendelenburg position causes abdominal contents to push the diaphragm cephalad along with all of the mediastinal structures (48). This cephalad movement reduces the lung′s functional reserve capacity (FRC), decreases pulmonary compliance, and predisposes to atelectasis (48).

This potential risk might be lowered by reducing tidal volume, increasing respiratory rate, and allowing permissive hypercarbia (49). In the pressure control- volume guaranteed ventilation (PC-VG) mode the ventilator functions as a pressure control ventilator, but tidal volume is also set (49). The advantage of this mode is the combination of the decelerating inspiratory flow pattern of the pressure-control mode and control of arterial CO_2 via guarantee of tidal volume and ultimately minute volume (50). Therefore PC-VG mode can improve pulmonary function and reduce incidence of atelectasis.

Perioperative Fluid Management

Administering too much fluid can lead to increased interstitial lung water, pulmonary edema and pneumonia, which can lead to pulmonary complications (lung injury)(51, 10).

A randomized controlled trial revealed that low intraoperative fluid regimens were associated with lower transfusion and fluid replacement requirements, and subsequently better clinical outcomes (52).

Avoidance of fluid excess is the first goal in perioperative fluid management. Goal directed fluid therapy can improve postoperative outcomes in moderate, and high risk patients (53). Minimization of preoperative fasting, early resumption of oral intake, avoidance of bowel preparation can reduce the volume of intravenous fluid requirement.

Postoperative Analgesia

Many meta- analyses have demonstrated improved outcomes with thoracic epidural analgesia (TEA) compared with opioid-based analgesia, including pain, complications, post-operative nausea and vomiting (PONV) and insulin resistance (54-58).

A randomized, controlled trial showed that thoracic epidural analgesia yielded significant improvement in pulmonary function, most likely due to a more profound postoperative analgesia (59). Higher forced expiratory volume in 1 s (FEV1.0) and peak expiratory flow rate (PEFR) were reported on postoperative days 2 and 3 in the thoracic epidural group than in the control group (59). Oxygen delivery and mixed venous oxygen saturation were higher in the epidural group (59). Another prospective, randomized, controlled trial demonstrated that high TEA decreases postoperative pain and atelectasis and improves pulmonary function in patients undergoing coronary artery bypass grafting (CABG) surgery (60).

Early Mobilization

Combining forced mobilization with nutritional support results in improved muscle strength but only during the early postoperative phase (61, 10). Early mobilization has been postulated to reduce chest complications and may counteract insulin resistance from immobilization (62, 10).

Early mobilization was shown to improve forced vital capacity, maximum voluntary ventilation, and arterial oxygenation (63). Mobilization results in increased tidal volumes which may assist the reversal of atelectasis leading to improve gas exchange (64). Another observation study showed that early mobilization resulted in significant increase in minute ventilation, and tidal volume (65). Early mobilization also significantly increases inspiratory flow rates and rib cage displacement (65). Therefore, early mobilization can improve pulmonary function, reduce postoperative pulmonary complications.

In conclusion, eight out of 21 ERAS elements play very important roles in preventing lung injury, reducing postoperative pulmonary compli-

cations. Three other elements can reduce the volume of intravenous fluid requirement; indirectly prevent pulmonary edema. These ERAS elements can prevent lung injury, reduce complications, enhance recovery, reduce length of stay, and lower the cost.

Declaration of Interests

No potential conflict of interest relevant to this review was reported.

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