Clinical pathway for thoracic surgery in the United States

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Abstract: The paradigm for postoperative care for thoracic surgical patients in the United States has shifted with efforts to reduce hospital length of stay and improve quality of life. The increasing usage of minimally invasive techniques in thoracic surgery has been an important part of this. In this review we will examine our standard practices as well as the evidence behind both general contemporary postoperative care principles and those specific to certain operations.

Keywords: Thoracic surgery; postoperative care; fast track; protocol

Introduction

The paradigm for postoperative care for thoracic surgical patients in the United States has shifted with efforts to reduce hospital length of stay and improve quality of life. The increasing usage of minimally invasive techniques in thoracic surgery has been an important part of this. In this review we will examine our standard practices as well as the evidence behind both general contemporary postoperative care principles and those specific to certain operations.

General principles

There are multiple goals of postoperative care for the patient, which can be viewed from the perspective of both the patient and the hospital/health care delivery system. If viewed broadly, these goals can include:

(I) Minimize recovery time;
(II) Decrease the physical impact of the operation on the patient;
(III) Minimize complications from the operation;
(IV) Evaluate/treat complications that do occur.

Concepts such as "recovery time" can encompass a number of different metrics, such as length of postoperative hospital stay, return to normal activities of daily living, and return to work. The goals of postoperative care can conflict with each other. For instance, decreasing the length of hospital stay could theoretically come at the cost of increased rates of readmission or emergency room visits.

Perioperative measures

The postoperative care of patients truly begins preoperatively, as interventions delivered before and during surgery can impact the postoperative morbidity experienced by patients.

Pulmonary rehabilitation

Enrollment in a pulmonary rehabilitation program preoperatively consisting of breathing exercises/training, working on effective coughing, and developing muscle strength and stamina can be beneficial in patients with borderline respiratory function for lung resection. Patients with non-small cell lung cancer (NSCLC) who underwent a preoperative pulmonary rehabilitation program for 6 days a week for 4 weeks showed significant increases in PaO_2 (60 ± 10 *vs.* 82 ± 12 mmHg, P=0.02), VO_{2max} (12.9 ± 1.8 *vs.* 19.2 ± 2.1 mL/kg/min, P=0.0001) and forced expiratory volume

in 1 second (FEV$_1$) (1.14±0.7 *vs.* 1.65±0.8 L, P=0.02) (1). These improvements can translate into decreased length of stay, fewer days with a chest tube, and lower rates of prolonged chest tube drainage (2). Other studies have corroborated the beneficial effects of pulmonary rehabilitation in patients undergoing lung resection (3).

Preoperative pulmonary rehabilitation has also shown to be useful for decreasing respiratory complications in patients undergoing esophagectomy (4). Interestingly, these studies evaluated all candidates for esophagectomy, not only those with compromised pulmonary function (5). We refer patients for pulmonary rehabilitation who have limited exercise capacity and/or borderline lung function for resection.

Smoking cessation

Preoperative smoking cessation has been shown to decrease overall complication rates in a wide variety of surgeries (6). The impact of smoking cessation of pulmonary complications after thoracic surgery is less well defined. Certain studies have shown benefit while others have not (7,8). Although non-smokers have decreased pulmonary complications compared to smokers, the risk of the latter is mitigated slowly by smoking cessation (9). However, for lung cancer specifically, smoking cessation is associated with decreased risk of all-cause mortality and recurrence, as well as development of a second primary tumor (10). Furthermore, the longer a patient has quit smoking preoperatively, the more likely they are to remain nonsmoking postoperatively (11). For these reasons, we recommend that all patients be counseled on smoking cessation prior to resection. In general we defer on operating on patients who have not made meaningful progress in terms of smoking cessation preoperatively.

Intraoperative measures

Attention to intraoperative details can lead to increased efficiency and decreased resource utilization combined with better postoperative outcomes.

Monitoring devices

The use of extraneous invasive monitoring devices adds time, cost, and the potential for complications to the process of thoracic surgery (12). We have eliminated the usage of arterial lines in the majority of our cases, reserving them

for situations in which we expect significant hemodynamic derangement or otherwise have a specific indication for them (e.g., severe pulmonary hypertension or cardiac dysfunction). We have similarly reduced our use of central venous catheters. We reserve Foley catheter use for patient who receive epidural catheters and/or are expected to be under anesthesia for 4 or more hours. We have found that our perioperative morbidity and mortality has not increased in spite of using fewer monitoring devices on increasingly complex and older patients (unpublished data). We routinely use noninvasive blood pressure monitoring, continuous ECG monitoring, pulse oximetry, and capnography.

Analgesia

We generally omit the use of epidural catheters in patients. Epidural catheter use can be associated with increased time, urinary retention, hypotension, and fluid administration. Increasing evidence supports the usage of paravertebral blockade as an alternative to epidurals. One meta-analysis of 18 trials showed that paravertebral blockade was equivalent to epidural analgesia in terms of early (48 hours and less) pain scores and narcotic usage, and better than epidural analgesia in terms of side effects such as urinary retention, nausea/vomiting, hypotension, and failed block (13). Liposomal bupivacaine, which is a formulation of bupivacaine that allows the continuous release of the anesthetic from liposomal vesicles over a 96-hour period, has also shown to be comparable in terms of efficacy to epidural analgesia during thoracic surgery (14). We generally perform a bupivacaine intercostal nerve block, which is similar to paravertebral nerve block (although it does not allow for continuous infusion postoperatively) on patients undergoing both open and minimally invasive thoracic operations. We also give pre-emptive local analgesia at the site of incisions prior to incision.

Airway management

We generally favor double lumen endotracheal tubes over single lumen tubes for airway management during thoracic operations. The placement of a double lumen tube allows for selective ventilation of the non-operative lung and we believe are more stable than using bronchial blockers, which are also more difficult to reposition once dislodged. However in patients with small tracheas or difficult airways, thoracoscopy can be done with the use of a single lumen tube with a bronchial blocker, or if a blocker cannot be

Figure 1 Lateral decubitus patient positioning.

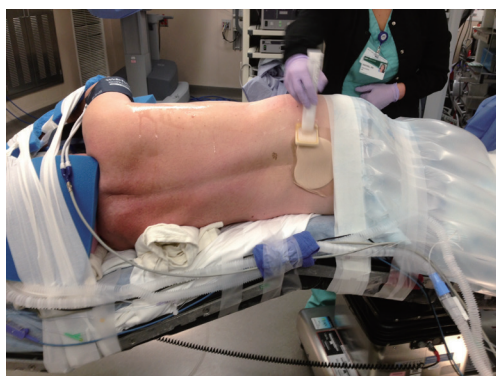**Figure 2** Anterior view of lateral decubitus positioning.

Figure 3 Posterior view of lateral decubitus positioning.

reliably placed, intermittent periods of apnea (15). This can be especially useful in short cases such as pleural effusion drainage, pleural biopsy, and pleurodesis. However, for performance of anatomic lung resections, esophagectomy, decortications, and more prolonged cases, selective lung ventilation is critical. An easy, reproducible method to ensure efficient, timely placement of the double lumen endotracheal

tube is described. The left-sided double lumen endotracheal tube of the appropriate size is used to intubate the trachea. A pediatric fiberoptic bronchoscope is placed through the bronchial lumen of the tube and driven down into the left lower lobe bronchus. The endotracheal tube is then slid over the bronchoscope, which facilitates passage of the bronchial lumen of the tube into the left lower lobe bronchus. The bronchoscope is then reinserted via the tracheal lumen and correct positioning of the tube is confirmed.

Positioning

Decreasing the time from entry to the operating room to incision decreases room utilization and costs, not to mention expediting the performance of cases by the surgeon during the day. Streamlining the process of positioning the patient is part of this efficiency. After proper placement of the double lumen tube is confirmed, the patient is turned on their side. Neither a bean bag or axillary roll is used, which minimizes equipment that needs to be procured before/during the case. The bed is then flexed, and the patients' arms are folded in front of them and positioned on the bed. An arm board is not used. Foam padding and blankets are used for the arms and head, and pillows are used between the legs, to ensure that the vulnerable spots on the patients' extremities are protected and nerve injury avoided. The patient is secured in the lateral decubitus position with straps over the thighs and tape holding the hip and arms/head in place. A lower body warming blanket is placed. Tube positioning is rechecked and patient tolerance for single lung ventilation is confirmed before draping. If a robotic case is being performed, monitoring lines and the ventilation tubing are consolidated into a single bundle with the assistance of towels and tape to avoid interfering with surgeon and assistant movement around the patient, and the bed is turned in the room as needed for docking of the robot. Photographs depicting patient positioning are shown in *Figures 1-3*.

Fluid/blood administration

A higher rate of fluid administration during thoracic surgery has been associated with an increased risk of acute lung injury and acute respiratory distress syndrome (ARDS) (16,17). An increased amount of fluid given intraoperatively (more than 6 mL/kg/hour) has been linked with an increase in cumulative postoperative pulmonary complications (defined as ARDS, need for intubation or bronchoscopy,

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prolonged air leak, atelectasis, pneumonia, and failure of lung to expand) after anatomic lung resection (18). Intraoperative fluid balance was also associated with an increased risk of postoperative acute exacerbation of idiopathic pulmonary fibrosis in patients with the disease undergoing anatomic lung resection (19). We collaborate with our anesthesiologists to consciously restrict the amount of fluid given during operations.

Ventilation strategies

Hyperventilation of the non-operative lung during thoracic surgery can decrease the amount of working space on the operative side. Furthermore, one randomized trial has shown that a protective lung ventilation strategy (FiO_2 of 0.5, tidal volume of 6 mL/kg, positive end-expiratory pressure of 5 cmH$_2$O, and pressure control ventilation) decreased pulmonary complications after lung cancer resection compared to conventional ventilation [FiO_2 1.0, tidal volume 10 mL/kg, positive end expiratory pressure (PEEP) of zero, and volume control ventilation] (20). Shorter duration of single-lung ventilation also seems to be beneficial in terms of reducing the rise in inflammatory mediators once the patient is returned to dual lung ventilation (21). Given the evidence that preoperative chemotherapy is associated with impairments in lung function and postoperative pulmonary complications, attention to oxygen concentration during subsequent lung surgery is important especially in these patients (22,23). We advocate minimizing the amount of FiO_2 and tidal volume utilized during single-lung ventilation for thoracic operations.

Postoperative measures

Fast-track protocols

The consistent management of postoperative care after pulmonary resection has been shown to reduce cost and length of stay (24,25). We emphasize avoidance of the intensive care unit (ICU), use of oral pain medications rather than intravenous pain medications or epidural catheters, early ambulation, minimizing postoperative intravenous fluids, and early feeding (jejunostomy tube feeding in esophagectomy patients on postoperative day 1). Our standard practice has translated to a median hospital length of stay of 2 days for robotic pulmonary lobectomy and 7 days for both robotic and open esophagectomy (26-28). In spite of our protocols, risk factors such as increased age (>70 years), high body mass index (BMI >35 kg/m^2), impaired

FEV_1 (<45%) and smoking history have been associated with increased likelihood of failure to "fast-track," or to have prolonged length of stay and/or complications (29). Specific interventions, such as avoiding epidural usage in patients >70 years and increasing assistance for ambulation and respiratory treatments for patients with obesity and poor pulmonary function, decreased the rate of morbidity in these populations (29).

Pain control

We employ multimodality therapy to optimize pain relief after thoracic operations. In addition to narcotics, we utilize lidocaine transdermal patches, acetaminophen, and ibuprofen for patients. In general patients who undergo minimally invasive thoracic surgery with video-assisted thoracoscopic surgery (VATS), laparoscopy, or robotic assistance do not require patient-controlled intravenous narcotic analgesia (PCA). Occasionally patients who are either tolerant to narcotics or otherwise have poorly controlled pain require PCA usage. Breakthrough pain medication is made available for patients not on a PCA.

Postoperative care: lung resection

Chest tube management

The early removal of chest tubes, beyond facilitating earlier discharge, has been associated with more rapid recovery of parameters such 6-minute walk distance (30). Furthermore, chest tube removal at volumes of up to 500 mL of drainage per day has been shown to be safe (31). We generally remove chest tubes when daily output is less than this and no air leak is present, and have had only a 0.55% readmission rate for symptomatic recurrent effusion (32). The use of suction (as opposed to water seal) appears to prolong the duration of air leak (33,34). At our institution, patients are placed on water seal by postoperative day 1 following lung resection. Our algorithm for chest tube management in patients undergoing lung resection is shown in *Figure 4*. Those with significant pneumothoraces when placed on water seal may require the temporary use of suction. Pleurodesis with either talc or doxycycline is considered if a patient has a persistent air leak at 5–7 days (35). If the air leak persists, however, the chest tube can still eventually be removed; we have shown that 100% of patient discharged with an air leak after lung resection can have their chest tubes safely removed at a median of 16.5 days after an operation, even if a pneumothorax and/or air leak is still present (36). Patients who are discharged home
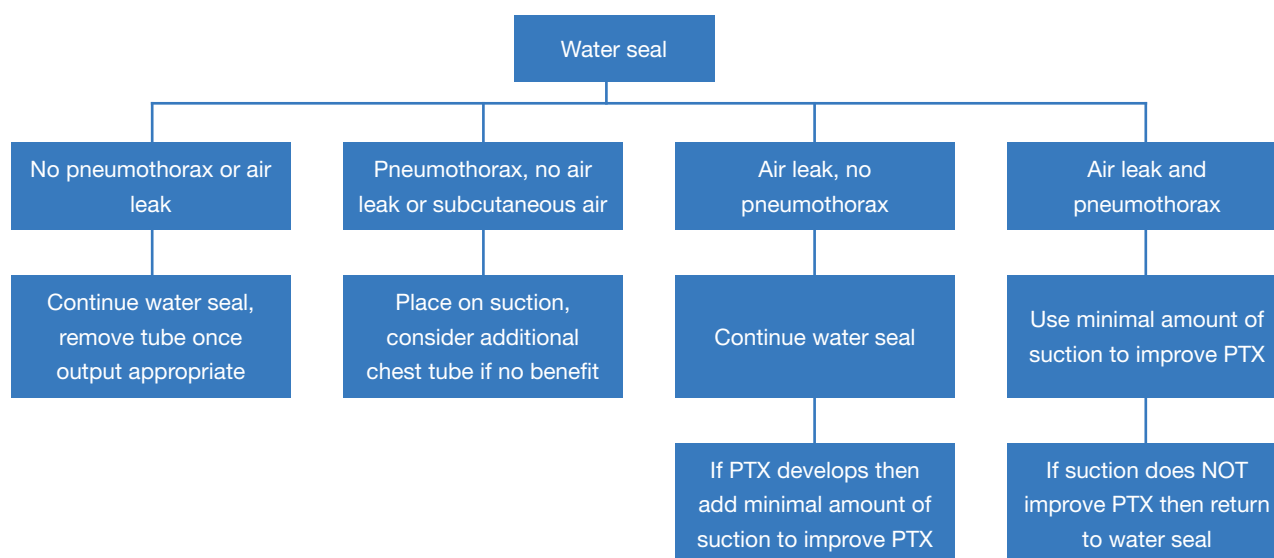
Figure 4 Algorithm for management of air leaks following pulmonary lobectomy. If air leak is greater than 750 mL/min on Thopaz on POD#2 then prepare for outpatient Thopaz usage. Place on Thopaz then discharge home. Remove chest tube when leak <20 mL/min for 2 days. After 3 weeks, can remove chest tube even if air leak persists if pneumothorax does not increase and no subcutaneous air is present (can perform clamp trial if desired). PTX, pneumothorax; POD, postoperative day.

with a chest tube are kept on oral antibiotics until removal. In terms of method of removal, chest tubes that are removed on end expiration had fewer pneumothoraces after removal than those removed at full inspiration (37). This is our preferred technique.

Digital air leak devices

The use of digital air leak devices allows for the quantification of air leaks present and the discharge of patients who require some degree of suction to maintain lung inflation. They have been shown to decrease the time to chest tube removal and duration of hospital length of stay (38,39). We generally convert patients with an air leak from standard chest tube drainage device to Thopaz digital thoracic drainage system (Medela Healthcare U.S.; McHenry, IL, USA) on postoperative day 1 if a significant air leak is present on exam. Patients can be safely discharged home on the device, with few device-related malfunctions and/or readmissions (unpublished data).

Postoperative care: esophagectomy

Nasogastric (NG) tube

We do not use NG tubes routinely after esophagogastrectomy.

Although evidence exists that NG tube decompression with a "sump" type tube decreases tracheal acid exposure and respiratory complications after esophagectomy, this data was derived from patients undergoing esophagectomy via a left thoracoabdominal approach, which is a fairly morbid incision (40). Furthermore, the presence of a NG tube following esophagectomy does not appear to decrease the risk of anastomotic leak, or the incidence of nausea, vomiting, and/or distention after esophagectomy (41). We believe that the disadvantages of NG tubes including discomfort and decreased mobility outweigh any perceived benefit in the typical patient.

Fast track

Patients undergoing esophagectomy at our hospital generally go to the post-anesthesia recovery room and then to a "step-down" floor with continuous telemetry following the operation. Tube feeding via jejunostomy tube placed at the time of the operation is initiated on postoperative day 1. Nutritional support is quickly increased over the next 24–48 hours as long as the patient does not develop significant distention or ileus. The chest tube is removed once nutritional support is at goal and no chylothorax or obvious clinical leak is demonstrated. A clinical speech

Table 1 Fast-track protocol for patients undergoing robotic Ivor Lewis esophagectomy

Day of surgery
 Patient sent to floor
 Nasogastric tube placed to suction
 Monitor chest tube output and urinary outputs q4 h
 Continuous monitoring of heart rhythm and pulse oximeter
POD1
 Jejunal tube feedings at full concentration, starting at 20 mL/h
 Ambulate patient four times per day; physical therapy every day
 Chest tube to suction
 Strict aspiration precautions; head of bed at 30°; nasogastric tube suction
POD2
 Continue to ambulate patient a minimum of four times per day until discharge
 Increase rate of jejunal tube feedings, 10 mL/4 h
 Consult nutritional therapist
 Continue aspiration precautions; physical therapy
 Remove Foley catheter
POD3
 Increase rate of jejunal tube feedings until achieving goal rate
 Remove chest tube if no chyle and drainage <450 mL/d
 Consult speech pathologist
 Continue aspiration precautions; physical therapy
POD4
 Gastrografin swallow (or on POD5 if POD4 is a Sunday)
 Continue jejunal tube feeds
 If swallow shows no leak, advance patient to a full liquid diet and skip clear liquids
 Continue aspiration precautions; patient warned not to eat while drowsy or to lie recumbent within 3 h of eating
 Continue physical therapy
 Education on chewing and swallowing
POD5
 Advance to soft diet as tolerated
 Start compressing jejunal feedings by increasing rate and turning off for 4 h/d
 Continue aspiration precautions; physical therapy
POD6
 Nutrition education provided by dietician
 Set up home jejunal tube feedings
 Start to compress jejunal tube feedings 7 pm to 7 am
 Continue aspiration precautions; physical therapy
POD7
 Discharge home on soft diet with continued aspiration precautions and compressed tube feedings at night only

POD, postoperative day.

evaluation is generally performed on postoperative day 4 or 5, followed by a barium swallow if there is no bedside evidence of aspiration on the speech evaluation. Patients are discharged home on full liquids or a soft diet and full nutritional support at a median of 8 days after the robotic-assisted Ivor Lewis esophagectomy (manuscript in press). The "fast-track" protocol for patients undergoing esophagectomy at our institution is shown in *Table 1* (28).

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