# 15 Anesthesia for Pleural and Chest Wall Surgery

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## Introduction

As the incidence of lung cancer increases, the frequency with which chest wall and pleural cavity surgery occurs is likely to increase as well. Tumor invasion of the chest wall requiring resection and reconstruction, pleurodesis and drainage of malignant effusions will also rise in synchrony with cancer incidence [1]. The rise in these surgeries is in addition to the number of congenital chest wall diseases already being repaired regularly.

While pleurodesis is on the rise as the incidence of lung cancer increases, there has been a reduction in the amount of pleural cavity surgery performed to treat tuberculosis and empyema due to improvements of medical management and minimally invasive techniques. Decortication is the most commonly performed pleural cavity surgery and it involves excision of an empyema sac and/or thickened pleura from the lung and chest wall and can be done with a minimally invasive approach. However, anesthesiologists need to be aware of the Clagett procedure, rib resections and Eloesser flaps, because while these procedures are decreasing in frequency, they will still be performed when all other options are exhausted and for patients too ill to undergo surgery for thoracotomy, surgical decortication or muscle flap transposition [2, 3].

The Eloesser flap and Claggett's procedure are two surgical treatment options for patients with tuberculosis and pleural space infections associated with bronchopleural fistulae. The purpose of the aforementioned surgeries is to create a one-way valve that would allow the infected fluid from the chest cavity to passively drain without trapping air. The greatest differences between the Eloesser flap and a Clagett window is that the Clagett window is considerably larger and was designed to be a temporary measure to allow decontamination of the pleural space with a subsequent closure.

Chest wall and pleural cavity cases can be very challenging for even the most experienced anesthesiologist. Given the variety of surgical and physiologic derangements that may occur with these surgeries, extensive perioperative communication between the surgeon and the anesthesiologist is required for improved outcomes. Discussion should focus on intraoperative and post-operative physiologic changes, highlighting the mechanics of ventilation and the degree of surgical intervention needed. Additional discussion centered on surgical stimulation and postoperative pain management are warranted.

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## Preoperative Considerations

Patient who present for chest wall and/or pleural cavity surgery may often be weak and debilitated and they may often have difficulty at their presurgical baseline with oxygenation or ventilation. Severe chest wall deformities are often associated with restrictive lung defects. These patients may also be at risk for arrhythmias and outflow tract obstructions given heart location and displacement [4]. The preoperative evaluation should focus on the extent and severity of pulmonary disease and cardiovascular involvement. Patients in poor general health, at extremes of age, or with chronic obstructive pulmonary disease are known to be at increased risk for postoperative complications [4].

A thorough history and physical exam should be performed. In addition to the standard questions asked, areas of focus should include: quantitation of dyspnea, characteristics of cough and sputum, smoking status, and exercise tolerance. Also, if a patient is presenting for resection of chest wall cancer, investigation into chemotherapy regimen is important as agents such as adriamycin can be cardiotoxic and bleomycin will affect the lungs [5, 6]. Included in the physical exam should be a focus on the respiratory system. Patients need to be evaluated for breathing pattern and rate, baseline oxygen saturation, breath sounds, presence of pulmonary hypertension and cardiac murmur. Presence of wheezing, abnormal breath sounds, rales, or tracheal deviation suggest the need for further work up [7].

Preoperative studies that may need to be performed before thoracic wall and pleural surgery include: chest X-Ray (CXR), electrocardiogram (ECG), arterial blood gas (ABG), pulmonary function tests (PFTs), chest computerized tomography (CT) scan, cardiac stress test and/or evaluation of exercise function [8, 9]. CXR is required for evaluation of preexisting lung disease and the pre-op CXR can serve as a comparison study following empyema or other drainage procedures. Often times a CXR is not sufficient and CT scan may be required. Chest CT also provides information with regard to airway obstruction and chest wall deformities [8]. It aids the anesthesiologist in determining whether or not they can safely pass an endotracheal tube into the trachea, especially in the case of airway or anterior chest wall tumors. Pulmonary function tests (PFTs) are performed to aid in the assessment of baseline respiratory function. Severe chest wall deformities are often associated with restrictive lung defects; the implication for intraoperative management may be significant depending on the surgery planned. Pleural effusions or empyema often affect diffusion capacity of the lungs. Preoperative PFTs allow the anesthesiologist to determine the likelihood a patient will tolerate one lung ventilation and can help predict whether or not the patient is at increased risked for postoperative pulmonary complications. They can also predict the degree to which the pre-existing conditions may compromise the ability to ventilate adequately during the procedure [10, 11]. Patients with known COPD, asthma and emphysema should undergo baseline PFT testing. PFT results showing forced expiratory volume in 1 s (FEV1) ≤50% normal or ≤600 mL, Vital capacity (VC) ≤1700 mL and hypoventilation of large part of the lungs expressed as a FEV1/VC ratio ≤ 32–58% inform the anesthesia provider who is at risk for hypoventilation, hypercapnia, and other respiratory complications in the intraoperative and postoperative period.

A preoperative ABG will allow the anesthesiologist to determine the severity of the patient's underlying lung disease and also help predict if the patient is at increased risk for postoperative respiratory complications. Patients with a low PO2 and oxygen saturation of less than 90% on room air at baseline are at higher risk for postoperative complications including prolonged ventilation. In addition, patients who are hypercapnic (PaCO2 > 50 mmHg) on baseline ABG are at increased risk for poor outcomes as anesthesia can worsen hypercapnia leading to somnolence and prolonged intubation postoperatively.

Cardiac testing includes EKG, exercise stress testing and cardiac ultrasound [9]. Many of the patients presenting with chest wall deformities and large volumes in the pleural cavity are at increased risk for arrhythmias and outflow tract obstruction. This is due to cardiac displacement from the underlying disease and may require evaluation [4, 9]. Asymptomatic patients with no signs of concerning pathology on CXR or CT need no further evaluation than an EKG while preoperative cardiac testing should increase as symptoms or radiologic findings worsen. Further testing can include an echocardiogram or nuclear stress test.

Pulmonary and cardiac complications continue to be the major sources of morbidity and mortality for these patients [9]. Therefore, as with any surgical patient, patients should be evaluated and medically optimized by their primary care physician, cardiologist and/or pulmonologist prior to surgery. However, in the setting of emergent Eloesser flap and Claggett's procedures, patients are often unable to undergo testing given the acuity of the underlying illness and should be managed with the preoperative data that is available.

## Intraoperative Considerations

### Monitoring

Routine monitoring during chest wall and pleural cavity surgery should include pulse oximetry, end-tidal capnography, electrocardiogram, invasive or noninvasive blood pressure, and temperature. A Foley catheter is necessary during long procedures and in unstable patients; it may also be necessary when epidural analgesia is planned. Bispectral index or processed EEG can be considered. Arterial line placement is not required but should be considered for patient-specific factors or if surgical intervention may result in excessive blood loss or cause rapid hemodynamic changes. In certain procedures such as pectus excavatum repair (Nuss procedure), the anesthesiologist must be prepared for the possibility of hemorrhage, with appropriate intravenous (IV) access planned [12]. Invasive hemodynamic monitors such as central venous pressure (CVP) and pulmonary artery (PA) catheter are not indicated unless there are significant patient-specific factors such as severe lung disease, myocardial ischemia or anatomic vascular restrictions. A dynamic index such as stroke volume variation or other similar monitor may be used if blood loss is expected to be significant. The Nuss procedure also includes a risk of arrhythmia and hemodynamic disturbances from cardiac compression, requiring vigilance in monitoring hemodynamics during key portions of the case.

### Choice of Anesthetic

There are a variety of anesthetic options for pleural cavity procedures depending on the method and extent of surgery necessary, the need for lung isolation and the preference of the patient. Though most cases do not require lung isolation, when needed, general anesthesia with double lumen tube placement or bronchial blocker placement is utilized. Smaller procedures without lung isolation may be performed under epidural or regional anesthesia such as thoracic paravertebral block. Some procedures such as pleural effusion drainage, pleural biopsy, drainage of empyema, evacuation of hematoma, chest wall biopsy or lung biopsy may be performed under local anesthesia with monitored anesthesia care [13].

For patients having general anesthesia, choice of anesthetic agent involves the usual concerns including need for anesthesia, analgesia, and paralysis to facilitate mechanical ventilation and surgical exposure. Intravenous induction will typically involve administration of propofol, ketamine or etomidate, an opiate, and likely a muscle relaxant to facilitate intubation. Maintenance can be provided by inhaled or intravenous methods. Nitrous oxide should be avoided whenever pneumothorax might occur and as it will also expand the volume of blebs or endotracheal tube cuffs it should generally be discouraged in this population. Additional concerns in some instances include maintenance of hemodynamic stability and effects of agents on hypoxic pulmonary vasoconstriction. Generally, the intravenous anesthesia agents have less effect on hypoxic pulmonary vasoconstriction than do volatile agents [14]. In practice, the differences between the newer inhaled and intravenous agents effect on arterial oxygenation are minimal at clinically effective doses [15]. Avoidance of coughing and straining on emergence may be important in some chest wall surgeries to avoid development of subcutaneous emphysema. Administration of opiate, lidocaine, or dexmedetomidine may be useful to reduce coughing and straining during emergence.

## Lung Isolation

Lung isolation may be required in chest wall surgery that also involves the thoracic cavity. It is typically not required in the Nuss procedure as CO2 insufflation during thoracoscopy is adequate. If lung isolation is needed, it can be achieved using a bronchial blocker or double lumen endobronchial tube after interdisciplinary discussion with the surgical team and evaluation of the patient's particular situation.

A double lumen endobronchial tube has many advantages in that it allows better suctioning and CPAP to the deflated lung and better facilitates intermittent ventilation if needed. If a patient will require awake fiberoptic intubation, needs to remain intubated postoperatively or starts with a pre-existing endotracheal tube or tracheostomy with small stoma a bronchial blocker may be the preferred option. Placement of bronchial blocker or double lumen tube should be confirmed by fiberoptic bronchoscopy immediately prior to initiation of lung isolation and one lung ventilation. As with any case where one lung ventilation is employed, the anesthesiologist should remain vigilant for early detection and treatment of hypoxemia and hypercarbia.

Of particular interest are patients requiring one lung ventilation for pleural cavity surgery to treat bronchopleural fistula (BPF). A bronchopleural fistula is an opening between the pleural space and the central bronchial tree. This can occur due to trauma, infection, carcinoma, rupture of a bleb or most commonly after lung resection or pneumonectomy. Lung isolation in BPF cases is critically important to avoid significant air leak with positive pressure ventilation or more concerning, the development of tension pneumothorax. The patient should either have a pre-existing chest tube on the affected side or have one placed prior to induction of anesthesia and attached to active suction. An ideal scenario to avoid air leak from the affected bronchus is for an awake intubation with a double lumen tube with the bronchial tip placed into the healthy bronchus under direct visualization with fiberoptic bronchoscopy. However, awake intubation with a double lumen tube is quite challenging even with excellent topicalization and a cooperative patient. An alternative is for an inhalational induction with preservation of spontaneous respiration, standard laryngoscopy with initial placement of the bronchial cuff high in the trachea, then proceeding with fiberoptic bronchoscopy to guide the tip into the desired bronchus. Once the correct bronchus has been entered, one lung ventilation can ensue. The above maneuvers may not be necessary in a patient known to have a small BPF with a pre-existing chest tube on suction where a small air leak following standard induction and double lumen intubation is tolerated.

## Positioning

Positioning for chest wall surgery will depend on the location of the surgery and exposure required. Pressure points should always be checked, and positioning should always minimize the risk of nerve injury. Many of these patients will require surgery on the lateral chest wall and standard positioning precautions should help reduce the risks associated with the lateral decubitus position. Of note, the Nuss procedure for pectus excavatum often requires abduction of the left arm to obtain surgical access which has resulted in case reports of brachial plexus injury. Placing the left arm in an arthroscopy sling may reduce this occurrence [16].

## Intraoperative Complications

Serious complications can occur during chest wall surgery. During tumor resection of the chest wall there can be complications depending on the location and size of the tumor and involvement of surrounding structures. Bleeding may be extensive, and injury to the diaphragm or lung can occur. Resections involving three or more contiguous ribs may result in flail chest, leading to respiratory compromise during spontaneous ventilation if chest wall rigidity is not adequately restored during reconstruction. Respiratory complications are common after chest wall tumor resection and respiratory failure is the most common cause of postoperative mortality [17].

During the Nuss Procedure, complications include hemorrhage, pneumothorax, hemothorax, right ventricular puncture, cardiac compression and arrhythmia. The risk of pneumothorax and mediastinal and subcutaneous emphysema following the Nuss procedure continue into the postoperative period [18].

During pleurodesis and decortication surgeries there are infrequent complications of hemorrhage, subcutaneous emphysema and persistent air leak. Greater amounts of infection and scarring will lead to greater risk of hemorrhage. Complicated effusions or empyemas may require conversion from VATS to open thoracotomy on occasion [19]. Patients with active infections may develop sepsis before, during or after surgery and this should always remain high on the differential diagnosis of the anesthesiologist. During open window thoracostomy surgery for bronchopleural fistula there may be difficulty ventilating due to large air leak or development of a tension pneumothorax. Infectious material can spread via bronchopleural fistula to the lungs, compromising respiratory function.

There are a variety of complications that may occur during initiation of one lung ventilation, including airway trauma to teeth, pharynx, larynx, trachea or bronchus. Malposition of the tube tends to occur during surgical manipulation and cause trauma or airway obstruction and a fiberoptic bronchoscope must be available throughout the surgery. Depending on the severity, some complications may require prolonged intubation and hemodynamic support.

## Postoperative Pain Control

Chest wall surgery can be variable in the amount of pain experienced postoperatively depending on the extent of surgery. No matter which type of surgery is performed, pain in this region can be difficult to control because of the constant movement, tension and strain placed on the chest wall required for respiration. The dynamic nature of the chest wall increases nerve irritation after an incision, leading to increased pain. Muscle weakness from deconditioning, changes in chest wall mechanics, and pain can lead to significant post-operative pulmonary complications including atelectasis, pneumonia, and increased hospital stay [20]. The severity of these complications suggests the need to adequately control pain and actively encourage early postoperative pulmonary conditioning. Given the difficulty in controlling pain for a dynamic system, a multi-modal pain control approach is recommended to allow patients maximum relief while limiting adverse effects of individual therapies [21]. Regional anesthesia as a part of this multi-modal pain control approach is highly recommended for its low systemic adverse effect profile and patient comfort with pulmonary conditioning. Anesthesia providers should work closely with their surgical colleagues to determine the extent and exact location of the surgical procedure to determine if regional anesthesia is possible.

Pectoralis plane infiltration, also known as PEC blocks I and II, directly target thoracic wall innervation, specifically the medial and lateral pectoral nerves. Blocking of these nerves would adequately cover pain on the anterior to lateral chest wall which is ideal for superficial or soft-tissue anterior chest wall surgery. These blocks do not adequately cover the lateral or posterior chest wall or pleura, and are not recommended for use with surgeries focused on those areas. These techniques are relatively safe and easy to perform using ultrasound guidance, directly visualizing the pectoralis major, pectoralis minor, and serratus anterior, and their fascial planes. Visualization for placement of the local anesthetic of choice varies between the blocks but may easily be performed in tandem to accomplish the widest block. When used appropriately, these blocks decrease the dose of post-operative narcotic used and decrease VAS pain scores [22]. However, these blocks may be limited both by anatomical coverage and efficacy, as PEC blocks were shown to be inferior to paravertebral block when directly compared in breast surgery, requiring earlier and higher doses of narcotic rescue medication [23].

Thoracic epidural analgesia (TEA) is another popular technique for chest wall surgeries. TEA has a broader range of coverage, encompassing the posterior chest wall and often pleural innervation in addition to the anterior and lateral chest wall. The epidural spread of local anesthetic will also cover the thoracic sympathetic chain at similar levels to spinal nerves, which allows more visceral coverage as well as decreasing autonomic stress response and spinal nerve wind-up response to pain. Leaving an epidural catheter in place allows for an increased duration of pain control. This added pain coverage makes thoracic epidural analgesia an option for a broader range of surgeries including surgery requiring thoracotomy incision, posterior thoracic wall, intrathoracic, or axial skeletal surgery. In at least one study published in the Journal of Pediatric Anesthesia comparing TEA to chest wall catheters, thoracic epidural catheters were more successful for initial pain control after surgery in children undergoing Nuss procedure for pectus excavatum, with pain scores lower on postoperative day 1 [24]. In another study on the same procedure in a similar patient population, thoracic epidural catheters were shown to have lower pain scores to PCA-morphine, and had less incidence of post-operative urinary incontinence and nausea and vomiting [25].

TEA may exert some visceral effect by blocking the thoracic sympathetic chain. Sympathetic block with local anesthetic may lead to both arterial and venous dilation from decreased sympathetic smooth muscle tone, thereby decreasing systemic afterload and preload and reducing systemic blood pressure. For patients without adequate hydration, hypotension can be severe. Tachycardia associated with decreased preload may be undesirable in the patient with vascular or coronary disease or with outflow tract obstruction from anatomical defects. However, the sympathetic blockade may also be associated with decreased systemic catecholamine response and lead to fewer cardiovascular events when compared to traditional IV analgesia [26]. This suggests that patients with significant risk for perioperative cardiac morbidity secondary to increased systemic catecholamines, notably arrhythmia or ischemia, may benefit from TEA analgesia in the postoperative period.

Since the epidural spread of anesthetic is related to the volume infused, continuous TEA catheters allow the dose of anesthetic to be titrated to desired effect. Local anesthetic administered in the thoracic epidural space tends to stay fairly local, as negative thoracic inspiratory pressure keeps the medication from spreading inferiorly to the lumbar level by gravity. This lower volume of infiltration in combination with low concentration decreases the risk of local anesthetic systemic toxicity, though inadvertent intravascular injection may still occur. Given a continuous infusion and possible catheter migration, a high level of monitoring is required throughout the postoperative period. A multidisciplinary discussion with the surgical and medical teams regarding anticoagulation in the perioperative period is warranted if TEA catheter placement is planned.

Paravertebral nerve blocks (PVB) can have similar analgesia coverage to TEA, but because of laterality of placement, these blocks can be used to achieve unilateral blockade. These blocks can be extremely effective for analgesia [23, 27]. However, two studies published in 2017 examined patients receiving thoracotomy for lung tumor resection suggest TEA analgesia can be superior to PVB likely due to the wider block effect possible with TEA [28, 29]. An advantage of PVB compared to TEA is that the anesthesiologist can directly determine which levels are blocked, not relying on spread of medication through the epidural space which is variable. Furthermore, PVB may be possible when TEA may be contraindicated as in spinous process injuries, or the severely intravascularly depleted patient at risk for hypotension or tachycardia with TEA [27]. There also exists the option to leave a paravertebral catheter in place following initial injection for increased duration of analgesia.

Intercostal nerve blocks are similar in both technique and advantages to a paravertebral block, as similar individual thoracic nerves can

**Table 15.1** Table showing the anatomical coverage of each type of nerve block discussed

| Nerve block type | Anatomic coverage for analgesia | | | | | Associated hypotension |
|---|---|---|---|---|---|---|
| | Anterior chest wall | Posterior chest wall | Pleura | Viscera | Unilateral/ directional | |
| PEC I and II | + | – | – | – | + | – |
| TEA | + | + | + | + | – | + |
| PVB | + | + | + | + | + | +/– |
| ICNB | + | + | – | – | + | – |
| Intrapleural catheter | – | – | + | + | + | – |

*PEC* pectoralis fascia infiltration, *TEA* thoracic epidural analgesia, *PVB* paravertebral nerve block, *ICNB* intercostal nerve block

be targeted for analgesia which can decrease the need for post-operative narcotic doses [30]. The major theoretical advantage to this technique is a more lateral or peripheral block, allowing for more accurate medication placement as local anesthetic spread is less likely to occur medially to the contralateral side or craniocaudally [31]. This also decreases the risk of inadvertent dura puncture, high spinal, and sympathetic block. The risk of inadvertent pleural puncture and pneumothorax remain present with this technique. Unfortunately, the duration of these blocks is limited by the excellent perfusion of the intercostal area.

Local infiltration of local anesthetics can be prolonged with safe continuous infusion pumps. The surgeon can infiltrate local anesthetic medication, liposomal bupivacaine or insert medication delivery catheters directly into the pleural or surgical plane. This allows for direct analgesia to the site. In a study from the Mayo Clinic, pleural On-Q pumps with low-dose continuous bupivacaine had equal analgesic effects to thoracic epidural catheter after minimally invasive repair of petus excavatum, and even had some implicit patient preference, though this latter measure was not directly measured [32]. The study out of Nemours Children's Hospital at DuPont noted that while TEA catheters had better pain scores on POD 1 of the Nuss procedure, every subsequent day the chest-wall catheters has equal analgesic effect to the TEA group [22]. The On-Q pump allows for continuous low-dose analgesic medication delivery in a safely secured method. This combination allows for maximal safety profile, though is not without theoretical risks; a catheter can always migrate and safety mechanisms must be properly initiated to avoid overdose. There is minimal risk for spinal or nerve injury, hypotension, or inadvertent pneumothorax with direct placement by the surgeon. Table 15.1 shows the anatomical coverage of each type of nerve block discussed.

Opiate medications are unlikely to be avoided entirely in these painful surgeries given their efficacy for analgesia. However, their side-effect profile can be severe and every effort at a balanced analgesic approach is recommended. As some patients cannot tolerate any of the regional techniques listed above, whether from allergy, refusal, or practicality of placement, total parenteral analgesia may occasionally be necessary. Opiate medications are the mainstay of this treatment as their Mu and Kappa agonist activity effectively dulls pain recognition in the central nervous system. The practical anesthesiologist should be aware of the most common and the most dangerous adverse effects of these medications. The most common adverse effects are constipation, post-operative ileus, urinary retention, and sedation. The more dangerous adverse effects are primarily related to respiratory depression at higher doses, which may be necessary to treat the severity of pain these patients experience, yet this population remains at particular risk for complications related to hypoventilation in the postoperative period. As such, other systemic non-opiate adjuncts should be considered: acetaminophen, NSAIDs, neuropathic pain medication such as gabapentin, and/or ketamine. There is also role for non-medication adjuncts, including patient education, music therapy, a TENS device, or hotcold temperature therapy [21]. It is important to note, however, that a study published in a 2011 Journal of Anesthesia noted that a single dose of perioperative ketamine prior to incision intended to prevent inflammatory cascade response showed no improvement in post-operative pain scores or plasma levels of inflammatory markers in thoracic surgical patients [33].

## Postoperative Complications

The risk for post-operative complications after chest wall surgery is related to the type of surgery and extent of surgical correction of thoracic wall defects. Anesthesiologists need to be aware of these potential complications as often times these patients will need to return the operating room. The most common complications include device malfunction (such as a broken wire in the Nuss Bar placement), pneumothorax, hemothorax, wound infection, hypoxemia, severe pain, post-thoracotomy pain syndrome, pleural effusion and failure of surgical goal [34, 35]. A major concern for patients recovering from chest wall surgery is undertreated pain causing splinting and respiratory insufficiency. When planning an anesthetic and analgesic approach to these cases, the patient's risk for postoperative respiratory failure must be of paramount concern. The decision to recover a patient in the ICU versus a ward bed should take into account the patient's baseline respiratory function, extent of surgical involvement, concern for respiratory insufficiency and additional co-morbidities. The incidence of post-operative hypoxemia related to hypoventilation can be higher after thoracic surgery than for major abdominal surgery, though this is less commonly monitored [35]. Post-Thoracotomy Pain Syndrome (PTPS) is unfortunately common, having an incidence of 25–60% of thoracotomy incisions [36]. Longer hospital stay and increased post-operative opiate use in the first three days after surgery were indicative of patients later diagnosed with PTPS, though no major or modifiable risk factors are currently known for preventing PTPS [37].

In summary, patients presenting for pleural cavity and chest wall surgery have variable pathologies and are often high risk for complicated procedures. A detailed discussion with the surgical team is of the utmost importance in order to tailor the anesthetic appropriately to allow for the best possible outcome.

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