Anesthesia for thoracoscopy: An overview

JOHN J. FAIR, CRNA, MSN
Weirton, West Virginia

Advances in technology have provided the means to reduce the length of stay for some surgical patients while offering increased quality of care. Videoscopic surgery is a rapidly expanding technology with increasing applications. When used in place of open thoracotomy, thoracoscopy offers the patient a less traumatic treatment modality. This procedure presents challenges to the anesthetist in choosing anesthetic technique, patient monitoring, and maintenance of cardiorespiratory function in the presence of pneumothorax and a variety of coexisting disease states.

Key words: One-lung anesthesia, thoracoscopy, videoscopic surgery.

Introduction
In the past, thoracoscopy (pleuroscopy) had been used to diagnose and treat intrathoracic disease processes, such as pulmonary tuberculosis.1 The popularity of the procedure was declining until recent advances in videoscopic technology restored interest in it. By avoiding the trauma associated with an open thoracotomy, patients experience less pain and fewer postoperative complications, decreased intensive care unit time, and shorter hospital stays.2 The pathophysiologic and anesthetic considerations for a patient who is undergoing thoracoscopic procedures can present a challenge to the nurse anesthetist.

History
Over the past 50 years there have been tremendous advances in surgical techniques and in the understanding of pathophysiology. One of the more recent developments to have an influence on surgical technique is the enhancement of videoscopic technology. Thoracoscopy is a surgical procedure that has enjoyed renewed interest as a result of this improved technology.

The thoracoscope is derived directly from the cystoscope, which was invented by Bozzini in 1806.3 Because only a candle was available as a light source, applications of the cystoscope were severely limited by poor illumination of the body cavities, a factor that resulted in the technique's failure to gain widespread acceptance. Subsequently, the invention of the incandescent light by Edison led to the first real advances. Newman incorporated an electric light into the cystoscope in 1883,4 and Kelling is credited with being the first to use the cystoscope for viewing the pleural cavity in dogs.5

The early popularity of using the cystoscope for pleural procedures originated primarily in Europe, where Jacobaeus reported a series of cases in 1921 in which thoracoscopy was used to treat pulmonary tuberculosis and pleural effusion.1 Acceptance of the procedure as a diagnostic and treatment modality varied. Some felt the rate of accuracy in diagnosis was unacceptably low, whereas others felt thoracotomy was a superior means of examining the entire pleural cavity. Development of antibiotics to treat tuberculosis led to the virtual cessation of the Jacobaeus thoracoscopy procedure.5
Aside from tuberculosis, most intrathoracic diseases required histologic evaluation of pleural tissue for definitive diagnosis. Although highly traumatic, rib resection and open thoracotomy were effective means of obtaining tissue, because the less traumatic needle biopsy yielded inconsistent results. However, thoracoscopically directed biopsy was viewed by some as being preferable to the blind introduction of a biopsy needle. Today, recent improvements in videoscopic equipment and the push to hold the line on healthcare costs have once again generated interest in thoracoscopy as an alternative to open thoracotomy.

**Procedure**

The thoracoscopic procedure involves placing the patient in the full lateral decubitus position, then prepping and draping as usual for thoracotomy. Using local, regional, or general anesthesia, a single stab wound is made, and a trocar is introduced into the pleural cavity. This is commonly done at the level of the 4-5 or 5-6 intercostal space, but it may be adjusted to accommodate a particular case.

When general anesthesia is employed, an endobronchial tube can be used so that the ipsilateral lung can be collapsed before trocar insertion to protect it against inadvertent parenchymal damage. Air is permitted into the pleural space, effusions can be drained, and samples can be collected. The rigid thoracoscope is then introduced to inspect the pleural surfaces. If necessary, another trocar may be introduced and used to insert a probe, suction, cautery, or other instruments to aid in the procedure. Biopsy specimens may be obtained or other procedures carried out by either direct visualization or videoscopic equipment.

When the trocars and cannulae are inserted, a partial pneumothorax is created. The extent of lung deflation is limited by the seal formed around the cannula by the tissues of the chest wall. The partial pneumothorax is usually well tolerated in the selected patient. Occasionally, despite careful screening, it is not tolerated, necessitating the use of general anesthesia. The potential difficulties of inducing general anesthesia and securing the airway in the lateral position must be considered in the anesthetic plan. Return of the patient to the supine position for induction is probably the best approach to the situation.

Before concluding the procedure, chemical pleurodesis (talc or tetracycline) or chemotherapeutic agents (bleomycin or cyclophosphamide) can be instilled to treat the patient with repeated episodes of spontaneous pneumothorax or intrapleural carcinoma. Because of scarring of the lung surface and eventual adherence of the lung to the chest wall, use of these agents should be limited to patients in whom a subsequent thoracotomy is not thought to be indicated. The trocars are then removed, and a water-sealed drain (chest tube) may be inserted through one of the original incisions. The lung can then be reinflated and the remaining incisions sutured.

**Pathophysiolog**

In the awake, spontaneously breathing patient in the lateral position, the relationship of blood flow to ventilation is similar to that in the erect individual. The dependent lung is better perfused as a function of gravity, and its ventilation is also greater than that in the nondependent lung. This is a result of the dependent hemidiaphragm being displaced upward into the chest by the abdominal viscera to a greater degree than the nondependent hemidiaphragm. The resultant increase in excursion of the dependent hemidiaphragm produces increased ventilation of the dependent lung. The combination of these factors assists in the preservation of a good ventilation/perfusion (V/Q) match.

The introduction of a limited pneumothorax has little effect on V/Q match in the patient, but provided the seal around the thoracoscope is adequate to prevent an open chest situation (free movement of air between the atmosphere and the hemithorax). Anesthesia providers should recognize that their patients are often in a compromised state and that the V/Q match may be impaired before surgical intervention.

Regardless of the patient's position, an open chest with spontaneous respiration can result in two adverse conditions. Shifting of the mediastinum toward the closed side of the chest on inspiration decreases the volume of gas that is drawn into the lung on the unaffected side and can result in inadequate ventilation. This shift can also result in circulatory changes that resemble shock. Paradoxical breathing may also take place between the two lungs so that gas moves from the lung in the open hemithorax to the lung in the closed hemithorax on inspiration and the reverse on exhalation. The severe distress that can result in such situations requires immediate induction of general anesthesia and initiation of positive pressure ventilation.

General anesthesia results in no change in pulmonary blood flow in the patient in the lateral position, because the dependent lung continues to receive greater blood flow than the nondependent lung because of the effect of gravity. During general anesthesia, ventilation changes do occur in these patients.
There are several reasons why the nondependent lung receives a relatively larger portion of the tidal volume than the dependent lung. The loss of functional residual capacity that is associated with general anesthesia results in compliance changes that favor ventilation of the nondependent lung. In addition, the weight of the abdominal and mediastinal structures acts to restrict ventilation of the dependent lung.

Opening the thoracic cavity does not create significant changes in pulmonary blood flow, but it has a great effect on ventilatory distribution. Spontaneous respiration will result in paradoxical ventilation, so positive pressure ventilation is indicated in this situation. Positive pressure ventilation will result in a relative hyperventilation of the nondependent lung, since it is no longer restricted in its movement by the chest wall, while the dependent lung continues to be less compliant, a situation that will result in a less favorable V/Q match. The addition of a muscle relaxant may compound the problem by removing the resistance offered by the muscle tone of the diaphragm. Because the dependent hemidiaphragm encounters more resistance from the abdominal contents than the nondependent hemidiaphragm, the latter is more easily displaced by positive pressure ventilation.

Anesthetic considerations

For the purposes of this discussion, local and regional techniques will be addressed together, since the patient will be breathing spontaneously in both cases. Physiologic considerations for ventilator-dependent patients who have local or regional anesthesia are the same as those of the general anesthesia patient with controlled positive pressure ventilation.

Local/regional and general anesthesia techniques all have specific advantages and disadvantages in these procedures. Rusch and Mountain feel that the use of local/regional anesthesia eliminates the stress of general anesthesia for patients who are too frail to tolerate it. Studies by Oldenburg and Newhouse and by Farshou, Madsen, and Viskum indicate that changes in blood gases and in cardiac rhythms are minor when thoracoscopy is performed under local anesthesia in the spontaneously breathing patient.

Bloomberg cites an initial preference for the use of local anesthesia for examination of the pleural space and lysis of adhesions that are thought to be "generally painless." He notes that he had used general endotracheal anesthesia for his "own recent thoracoscopies." The reasons Bloomberg cites are better control over the degree of collapse of the nonventilated lung and the ability to determine whether the lung will reexpand in cases where pleurodesis is a consideration. Pain resulting from instillation of talc or "other substances" is another factor in favor of general anesthesia cited by Bloomberg, who concludes that "... an endotracheal tube provides a safety factor that should not be ignored .". He also observes that the ability of Borchert and associates to stabilize their patients physiologically during thoracoscopy with induced pneumothorax with "high oxygen concentrations through an endotracheal tube" is an indication for this approach. Weissberg also advocates the use of general anesthesia, citing many of these same considerations. Anesthetic technique selection is based on the condition of the patient, the skill and gentleness of the surgeon, and the requirements of the procedure to be performed.

Preoperative evaluation

Preoperative attention to particular problems can reduce the frequency and severity of complications. Preoperatively, the patient should be evaluated for factors that might place him or her at risk in the perioperative period. Conditions that are predictive of a high incidence of postoperative complications include cardiac disease, infection, dehydration, electrolyte imbalance, wheezing, obesity, cor pulmonale, cigarette smoking, and malnutrition. Conditions that might warn of intraoperative oxygenation difficulties include those already mentioned as well as chronic lung disease, tuberculosis, and pleural effusions.

Monitoring for local or regional anesthesia

Monitoring for a patient who is undergoing thoracoscopy under local or regional anesthesia should include an ECG, noninvasive blood pressure, and pulse oximetry. The need for arterial cannulation for continuous blood pressure monitoring and serial blood gas analysis can be determined by the patient's condition and should be seriously considered for patients with a demonstrated potential for respiratory compromise. Patients who require thoracoscopy have some degree of existing pulmonary disease and may not be suitable candidates for the trauma of open thoracotomy because of their disease states. Arterial blood gas monitoring should be considered for thoroscopic procedures. The ability to perform serial blood gas analyses, as well as continual blood pressure measurement, makes this an attractive option.

Local/regional anesthesia. Local anesthesia consists of infiltrating the site of the trocar insertion with lidocaine or another local anesthetic agent. Regional techniques employ intercostal
nerve blocks, usually two levels above and below the proposed sites of trocar insertion. Intercostal blocks have the advantage of anesthetizing the parietal pleura, thus increasing the patient’s comfort and tolerance of the procedure. Inclusion of a stellate ganglion block in the regional anesthetic can help suppress cough reflexes provoked by manipulation of the lung during the procedure. Use of benzodiazepines, opioids, or propofol for sedation may be appropriate. The inspired concentration of oxygen ($F_{1O_2}$) should be supplemented with a face mask or nasal cannula for all patients who are receiving local or regional anesthesia.

- **General anesthesia.** General anesthesia has some advantages in thoracoscopy. Its use ensures control of the airway and allows for isolated lung ventilation. It also avoids having to switch from local to general anesthesia under less-than-ideal conditions.

- **Anesthetic agents.** The choice of agents is governed by the needs of the patient and the surgical requirements of the anticipated procedure. Any of the induction agents that are currently on the market may be used. The bronchodilating effects of ketamine might be beneficial for the patient with bronchospastic disease, while thiopental might be contraindicated in this same patient. Anesthesia can be maintained with any of the volatile agents, which allow for administration of 100% oxygen while they reduce airway irritability. Intravenous agents such as propofol may also be used in conjunction with opioids and/or benzodiazepines. Use of muscle relaxants should be limited to those without histamine-liberating properties to avoid untoward cardiovascular or pulmonary effects. Vecuronium or pancuronium are probably the agents of choice, as long as an increase in heart rate, which is sometimes seen with pancuronium, will not compromise the patient. The anticipated length of the procedure can then be the determining factor.

**Monitoring for general anesthesia**

Monitoring the patient for general anesthesia during thoracoscopy should include ECG, noninvasive blood pressure apparatus, and pulse oximetry. Temperature monitoring, esophageal stethoscope, and peripheral nerve blockade monitoring should also be employed. End-tidal carbon dioxide ($ETCO_2$) and/or mass spectrometry monitoring can be extremely useful in the evaluation of blood carbon dioxide ($CO_2$) levels and alterations. Arterial cannulation for blood pressure monitoring and serial blood gas determinations are essential for the patient who is undergoing thoracoscopy with one-lung ventilation.

- **One-lung ventilation.** Use of a double-lumen endobronchial tube should be considered routine for thoroscopic procedures. Positive pressure ventilation of the lung that is undergoing examination can interfere with its visualization and manipulation. The possibility of infection, blood, or fistulae in the affected lung also might warrant its isolation. An added benefit of using a double-lumen tube is the ability to selectively reinflate the affected lung at the conclusion of the procedure.

Many types of double-lumen tubes are available, each with its own characteristics. Robertshaw-type tubes are those most widely used. Some institutions routinely choose to insert left endobronchial tubes, as long as there is no contraindication, such as an intraluminal tumor. Left endobronchial tubes are somewhat easier to position, and their use avoids the possibility of occluding the bronchus to the right upper lobe of the lung.

Management of one-lung ventilation presents the anesthetist with a variety of challenges in maintaining gas exchange and avoiding hypoxemia. Use of an $F_{1O_2}$ of 1.0 is common in one-lung ventilation situations and is usually effective in maintaining arterial oxygen partial pressure ($P_{aO_2}$) above 150 mmHg. Other benefits of 100% oxygen include vasodilation of the ventilated lung, which combines with hypoxic vasoconstriction in the nonventilated lung to increase perfusion of the ventilated lung and reduce shunt.

The single most effective method of increasing $P_{aO_2}$ during one-lung ventilation is the application of continuous positive airway pressure (CPAP) to the nonventilated lung at 5-10 cm/H$_2$O pressure. This maintains airway patency and allows for oxygen uptake in the nondependent lung, improving oxygen saturation of arterial blood ($S_{aO_2}$). Continuous positive airway pressure should be applied after delivery of a tidal volume to the nondependent lung, thereby allowing the airways to remain open. A variety of devices have been developed for the application of CPAP, some of which are commercially available.

High $F_{1O_2}$ carries its own risks, such as absorption atelectasis and oxygen toxicity. Use of positive end expiratory pressure can help reduce the problem of absorption atelectasis. The duration of the procedures in question is normally not sufficient to pose a risk of oxygen toxicity. Lower levels of inspired oxygen can be used, provided $P_{aO_2}$ levels remain adequate, as determined by arterial blood gas analysis. Addition of intravenous agents might help the patient who cannot tolerate the degree of myocardial depression seen with the concentrations of inhalation anesthetic needed with 100% oxygen. The patient who is receiving bleomy-

136

*Journal of the American Association of Nurse Anesthetists*
cin chemotherapy also should be spared exposure to \( F_O_2 \) greater than 0.3 to avoid the development of adult respiratory distress syndrome.\(^9\) Addition of air to the inspired gas mixture may be preferable in such instances, along with manual, intermittent two-lung ventilation to maintain gas exchange and satisfactory \( S_aO_2 \) levels.

During one-lung ventilation, tidal volume should be kept at about 10-12 mL/kg, and the ventilatory rate should be adjusted to maintain normocarbia. High tidal volumes (above 15 mL/kg) increase resistance to blood flow in the ventilated lung and can increase the shunting of blood to the nonventilated lung, reversing the effect of hypoxic vasoconstriction. Low tidal volumes (less than 8 mL/kg) can decrease functional residual capacity and lead to atelectasis.\(^7\) Carbon dioxide elimination usually poses no problem in one-lung ventilation, provided tidal volume is adequate. Careful monitoring of carbon dioxide levels is necessary to avoid hypocapnia, which results from hyperventilation of the patient. Hypocapnia increases pulmonary vascular resistance in the ventilated lung, redirecting some blood flow to the nonventilated lung.

Positive end expiratory pressure to the dependent lung has been used with the intention of improving or maintaining functional residual capacity. The increased pressure in the dependent lung has been used with the intention of improving or maintaining functional residual capacity. The increased pressure in the dependent lung can result in increased pulmonary vascular resistance and redirection of blood to the nonventilated lung. Studies have shown mixed results from attempts to increase \( P_aO_2 \) through the application of positive end expiratory pressure to the dependent lung in these cases.\(^{14-17}\)

If these maneuvers do not produce a satisfactory level of gas exchange, resumption of two-lung ventilation is indicated. Such ventilation may be resumed on an intermittent basis in concert with the surgeon to complete the procedure as rapidly as possible. If the condition of the patient is unstable or in question, two-lung ventilation should continue until the situation is clarified or corrected.

Cardiac dysrhythmias are not uncommon during these procedures, especially when they are performed in the left hemithorax. Manipulation of the lungs and vessels in the chest can result in rhythm changes or hypotension, so appropriate pharmaceuticals should be readily available to treat such occurrences.

### Summary

Thoracoscopy offers some distinct advantages in the evaluation and treatment of intrapleural disease processes. Improved technology has renewed interest in the technique. Elimination of the trauma of open thoracotomy can hasten the patient's return to normal activities or to other treatment modalities. Limitation of postoperative pain can reduce intensive care unit and hospital stays, which help lower treatment costs. Avoidance of the chronic pain that is sometimes associated with an open thoracotomy can help reduce postoperative disability.

Anesthetic care of the thoracoscopy patient remains a challenge throughout the perioperative period. Management of the patient with coexisting diseases, use of one-lung ventilation, and care of the patient with compromised pulmonary function are all problems that anesthetists are likely to encounter more frequently as the use of thoracoscopy expands.

### REFERENCES


**AUTHOR**

John J. Fair, CRNA, MSN, received a diploma in Nursing from the Ohio Valley Hospital School of Nursing in Steubenville, Ohio, and a certificate in Nurse Anesthesia from Shadyside Hospital in Pittsburgh, Pennsylvania. He earned his BSN and MSN degrees from La Roche College in Pittsburgh. At the time this article was written, Mr. Fair was on the faculty of the University of Pittsburgh as an instructor in the Graduate Anesthesia Nursing Program. He is currently employed as a staff anesthetist by Aiken Anesthesia Associates at Shadyside Hospital in Pittsburgh.