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Video-assisted thoracoscopic surgery

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Video-assisted thoracic surgery is finding an ever-increasing role in the diagnosis and treatment of a wide range of thoracic disorders that previously required sternotomy or open thoracotomy. The potential advantages of video-assisted thoracic surgery include less postoperative pain, fewer operative complications, shortened hospital stay and reduced costs. The following review examines the surgical and anesthetic considerations of video-assisted thoracic surgery, with an emphasis on recently published articles. Curr Opin Anaesthesiol 13:000–000. © 2000 Lippincott Williams & Wilkins.

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Abbreviations

DLT	double-lumen endobronchial tube
ETT	endotracheal tube
LVRS	lung volume reduction surgery
OLV	one-lung ventilation
Pa_{O_2}	arterial oxygen pressure
VATS	video-assisted thoracoscopic surgery

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Introduction

Thoracoscopy involves intentionally creating a pneumothorax and then introducing an instrument through the chest wall to visualize the intrathoracic structures. Direct visual inspection of the pleural cavity has been performed since 1910, when Jacobeaus first used a thoracoscope to diagnose and treat effusions secondary to tuberculosis. The recent application of video cameras to thoracoscopes for high-definition magnified viewing, coupled with the development of sophisticated surgical instruments and stapling devices, has greatly expanded the ability of the endoscopist to do increasingly more complex procedures using thoracoscopy.

Compared with open thoracotomy, video-assisted thoracoscopic surgery (VATS) is considered to be 'minimally invasive'. The patient population tends to be either very healthy individuals undergoing diagnostic procedures, or high-risk patients undergoing VATS to avoid open thoracotomy. The potential advantages of VATS include less postoperative pain, earlier mobilization, lower overall morbidity, a shortened hospital stay with reduced costs, a cosmetic incision, and for some procedures, a reduced operating time.

Indications

The VATS approach was initially used for simple diagnostic and therapeutic procedures involving the pleura, lungs, and mediastinum [1]. However, VATS operations continue to replace many procedures that formerly required thoracotomy [2•]. For example, pulmonary operations using VATS have evolved from simple wedge and segmental resections to complete lobectomy. In selected patients a VATS lobectomy is a reasonable treatment option to thoracotomy for both adults [3] and children [4].

VATS operations can be used for all structures in the chest, and are not limited to the lungs, pleura and mediastinum. The heart and great vessels, the esophagus and diaphragm, the spinal column and nerves can all be operated on using VATS [5–13]. Each year has seen new, innovative applications of the technique. For example, intractable pain as a result of chronic pancreatitis can now be treated by inactivation of the major afferent pain nerves with the use of thoracoscopic splanchnicectomy [14]. The current indications for VATS procedures are shown in Table 1.

Table 1. Indications for video-assisted thoracoscopic surgery

General intrathoracic cavity
Diagnosis or biopsy of any intrathoracic structure
Laser application for treatment of tumors
Diagnosis and drainage of pleural effusions
Treat chylothorax
Debride empyema Retrieval of intrathoracic foreign body
Lungs
Wedge resection, segmentectomy, lobectomy
Closure of persistent/recurrent pneumothorax
Identification of broncho-pleural fistula
Pleura
Lysis of adhesions
Pleurodesis
Decortication
Mediastinum
Removal of mediastinal cysts
Thymectomy
Resection of posterior mediastinal neurogenic tumors
Esophagus and diaphragm
Tumor staging or resection
Resect esophagus
Repair diaphragm
Anti-reflux operations
Heart and great vessels
Pericardectomy
Diagnosis of cardiac herniation after pneumonectomy
Minimally invasive valve and coronary artery procedures
Ligation of patent ductus (infants)
Spine and nerves
Dorsal thoracic sympathectomy
Splanchnicolysis
Drainage of spinal abscess
Discectomy
Fusion and correction of spinal deformity
Trauma
Assess injury
Treat hemorrhage
Evacuation of clot

Lung volume reduction surgery

A special indication for VATS is lung volume reduction surgery (LVRS). LVRS procedures improve dyspnea and pulmonary function in selected patients with severe emphysema [15]. A thoracoscopic LVRS procedure can avoid the significant morbidity and mortality associated with similar operations performed by thoracotomy or sternotomy [16••].

Staged LVRS operations offer no advantage over a single hospitalization for bilateral LVRS [17]. Patients undergoing bilateral lung volume reduction via median sternotomy were compared with patients undergoing the procedure by bilateral VATS. Although the operating time was longer for the VATS operations, blood loss was significantly greater in the median sternotomy group [18].

In another study comparing LVRS using VATS with sternotomy [19], sternotomy patients required longer mechanical ventilatory support postoperatively, spent more time in the intensive care unit, had more days with an air leak, and were hospitalized longer. Although both surgical approaches offered equivalent functional outcomes [18–20], the overall hospital costs of a LVRS with the use of the VATS approach are significantly less than those of an LVRS using sternotomy [19].

Anesthetic considerations

The surgical approach to thoracoscopy involves creating a small (2–3 cm) incision in the lateral chest wall with the patient in the lateral decubitus position. Although minor operations (thoracentesis, pleural biopsy) can be performed through a single incision, two or three additional small incisions are usually made to allow the application of surgical instruments and stapling devices. A trocar is introduced into the chest cavity after the lung on that side has been selectively collapsed. The thoracoscope is then placed through the trocar into chest. At the conclusion of the procedure a chest drainage tube is inserted and the lung is re-expanded.

VATS can be performed using either local, regional, or general anesthesia. The simplest technique is to use a local anesthetic to infiltrate the lateral thoracic wall and parietal pleura. Alternatively, intercostal nerve blocks can be performed at the level of the incision(s) and at two interspaces above and below. Thoracic epidural anesthesia can also be used. For VATS procedures under local or regional anesthesia, an ipsilateral stellate ganglion block is often performed to inhibit the cough reflex from manipulation of the hilum. To anesthetize the visceral pleura, topical local anesthetic agents can be applied. Intravenous sedation with propofol may be needed to supplement the regional nerve blocks [21].

For VATS performed under local or regional anesthesia with the patient breathing without assistance, partial collapse of the lung on the operated side occurs when air is allowed to enter the pleural cavity. The resulting atelectasis may provide suboptimal surgical exposure. To facilitate visualization, carbon dioxide can be insufflated under pressure into the chest cavity to compress the non-ventilated lung. This may cause serious respiratory and hemodynamic changes. Gas insufflation can result in an increase in airway pressure, a rise in end-tidal carbon dioxide, mediastinal shift with hemodynamic instability and a drop in systolic blood pressure, and a decrease in hemoglobin oxygen saturation despite ventilation with 100% oxygen [22]. This clinical presentation resembles a tension pneumothorax [23]. These physiological responses to carbon dioxide insufflation into a closed chest cavity occur with pressures as low as 5 mmHg [24]. The complication can be reduced if the volume of gas is limited to 2 l/min and the carbon dioxide is insufflated slowly [25••].

The major disadvantage of VATS under local or regional anesthesia is that the patient must breath spontaneously.

This is usually tolerated for short periods of time [26], but for most VATS procedures a general anesthetic with controlled one-lung ventilation (OLV) is a better choice.

A single-lumen endotracheal tube (ETT) can be used for VATS under general anesthesia. However, if the lungs are not separated, positive-pressure ventilation to both lungs prevents lung collapse on the operated side, with inadequate surgical exposure. Therefore, lung separation with selective OLV to only the contralateral side is usually indicated. The lung must be completely collapsed to provide optimal surgical conditions. Failure to separate the lungs, with partial inflation of the operated lung, will jeopardize the operation and may make open thoracotomy necessary.

A double-lumen endobronchial tube (DLT) or bronchial blocker should be used to collapse the lung. A DLT is preferred because it provides selective ventilation of the contralateral lung, while allowing more rapid collapse of the ipsilateral lung. Carbon dioxide insufflation to compress the lung further is seldom needed. Opening the lumen of the DLT on the operated side to room air, and intermittently suctioning the tube further augments lung collapse. A DLT also allows the lung to be re-expanded under direct vision with a DLT.

General anesthesia for VATS is achieved with either intravenous or inhalational anesthetic agents, or a combination of both. The use of short- acting intravenous agents is important to allow the rapid emergence and recovery of airway reflexes.

Oxygenation

During general anesthesia the patient's ventilation and oxygenation are easily monitored by capnography and pulse oximetry. Most VATS procedures are short and are not associated with significant hypoxemia. Hemoglobin oxygen saturation usually remains stable, particularly if the patient is ventilated with a large tidal volume and 100% oxygen.

Continuous direct intra-arterial oxygen monitoring demonstrated substantial fluctuations in arterial oxygen pressure (Pao_2) and arterial carbon dioxide pressure ($Paco_2$) during routine VATS procedures [27]. The magnitude of these changes was unpredictable and was not reliably detected by non-invasive monitoring. However, changes were transient and did not appear to have any significant clinical relevance. During VATS procedures for LVRS, adequate oxygenation is not usually a problem although hypercarbia is common [28].

More serious prolonged decreases in Pao_2 can occur, which require immediate intervention. The position of the DLT should be immediately reconfirmed. During thoracotomy the usual treatment for hypoxemia is the application of continuous positive airways pressure to the operated upper lung. This has minimal impact on surgical conditions during a conventional open thoracotomy, but a partly distended lung will seriously interfere with surgical exposure during a VATS procedure. Therefore continuous positive airway pressure cannot be used during VATS.

Inhaled nitric oxide is a selective pulmonary vasodilator. In theory, if one could increase the blood flow to the ventilated lung during OLV by dilating the pulmonary artery on that side, shunt to the collapsed lung would be reduced and oxygenation would be improved. Inhaled nitric oxide (20 ppm) does not improve oxygenation in patients who become hypoxemic during OLV [29]. The combination of intravenous almitrine (a potent selective pulmonary vasoconstrictor) and inhaled nitric oxide dramatically increases Pao_2 in patients with acute respiratory distress syndrome [30]. The combination of inhaled nitric oxide and almitrine was shown to prevent hypoxemia in patients undergoing VATS [31].

Children

As surgical equipment becomes further miniaturized and operative techniques improve, VATS is being applied to younger and younger children [32,33•]. Experimental work with neonatal pigs demonstrates that OLV is well tolerated, with only minor alterations in gas exchange in newborn lungs [34].

VATS plays a special role in surgery for children with spinal deformities. Just as the procedures for pulmonary resection have evolved from simple biopsy to lobectomy, the endoscopic approach to the spine has grown from the simple drainage of abscess and single discectomy to the insertion of correctional implants and spinal fusions [35].

Recurrent, spontaneous pneumothorax in the pediatric population previously required open thoracotomy after failed conservative treatment with tube thoracostomy. VATS allows the accurate identification and removal of apical blebs with rapid recovery and reduced morbidity.

Thoracoscopic T2–3 sympathicolysis has become the treatment of choice for patients with severe, refractory essential hyperhidrosis. Thoracoscopic sympathicolysis does not affect postoperative pulmonary function in children [36].

As with VATS procedures in adults, selective collapse of the operated lung is essential. The usual choices for small children are either a balloon-tipped bronchial blocker [37] or placement of an ETT into the bronchus of the ventilated lung. Selective endobronchial intubation with an ETT may obstruct the upper lobe on the ventilated side causing hypoxemia [38]. Modified ETTs [39] and very small uncuffed DLTs [40] have been designed for infants and small children, but these special tubes are not commercially available.

For older children, small (26 and 28 Fr) conventional cuffed DLT are used. The 32 Fr BronchoCath DLT (Mallinckrodt Medical, Inc., St Louis, MO, USA) is particularly useful for thoracic spine procedures in the 10–12-year-old age group [41]. Pediatric size Univent tubes (Fuji Systems, Tokyo, Japan) can also be used for older children [42].

Postoperative analgesia

There is less postoperative pain after VATS than after similar operations performed by thoracotomy [43]. Although a potential benefit of VATS is the reduction of postoperative pain-related morbidity, further studies are needed to define the relative costs, risks and benefits of standard post-thoracotomy analgesic management using epidural opioids with less aggressive pain management after VATS [44].

For VATS, local anesthetic solutions can be infiltrated at the chest wall incision sites and administered as a bolus or by continuous infusion into the pleural cavity through the chest tube after the lung has been re-expanded. Post-thoracoscopy pain can also be treated with systemic or neuraxial opioids. Patient-controlled intravenous opioid analgesia is preferred. Thoracic or lumbar epidural opioids provide superior pain relief, but because of their side-effects are seldom indicated.

Transcutaneous electrical nerve stimulation is also effective in reducing analgesic requirements after VATS [43], and a role exists for non-steroidal anti-inflammatory drugs after VATS [45]. Both diclofenac and ketorolac were equally effective in reducing intravenous morphine requirements after VATS [46].

Complications

Approximately 9% of VATS patients experience some complications [47]. These include hemorrhage, subcutaneous emphysema, empyema, recurrent pneumothorax, pulmonary edema and pneumonia. Dissemination of tumor at the thoracostomy tube site is also possible [48•]. Persistent postoperative air leaks are quite common. Any structure that the surgeon manipulates or resects can be damaged.

Some patients may experience impaired gas exchange during and after the procedure. The pneumothorax created during VATS, especially when associated with carbon dioxide insufflation into the closed chest, can result in hypercarbia and inadequate ventilation, hemodynamic instability, and even gas venous embolism. Common to all VATS procedures is the need to be able to convert rapidly to an open thoracotomy when necessary.

Atrial arrhythmias, especially supraventricular tachycardia and atrial fibrillation can occur after all pulmonary resections and the incidence is similar after VATS or thoracotomy [49•].

Conclusion

Within a relatively short period of time, VATS has replaced many diagnostic and therapeutic procedures previously performed by traditional thoracotomy. By minimizing chest wall and muscle trauma, VATS not only causes less postoperative pain and fewer complications but also shortens hospital stay. VATS techniques continue to evolve and the refinement of instrumentation promises further applications for selected conditions. The anesthetic management of VATS involves the ability to separate the lungs to provide safe and effective OLV. The long-term role of VATS awaits studies of the economics, indications and end results of the specific applications of this technique.

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