Anesthesia for Pediatric Thorascopic Surgery

Joseph N. Farlo, MD
Assistant Professor Anesthesiology
Childrens Hospital Los Angeles

Introduction

Over the past decade advances in optical miniaturization systems used in endoscopes and computer assisted image guidance systems have led to an explosion of new minimally invasive surgical techniques for treating spinal deformities. Patients prefer minimally invasive surgery because such techniques give the promise of better cosmetic effect and reduced recovery times. Many of these techniques also promise decreased blood loss and better post-operative pulmonary function. Though equipment costs for start-up are steep, decreased hospital stay offers advantage to institutions as well.

As newly developed techniques in minimally invasive surgery begin to be more widely used the pediatric anesthesiologist will have to develop improved and reproducible techniques to accommodate the technological advances. Selective lung ventilation in small children and a critical understanding of a host of new possible complications that can arise during these procedures needs to be appreciated. Furthermore as new therapeutic modalities develop which offer surgery to patients previously not candidates, the anesthesiologist is called upon to care for a new patient population of younger more severely debilitated children.

Video-Assisted Thoracoscopy (VATS)

The thorascopic approach was introduced more than 75 years ago but has undergone multiple transformations with improved video capabilities. Modified long narrow instruments are passed through small skin incisions (portals) and visualization is achieved via small endoscopes with high quality video imaging. Although the external incisions are limited, the operative interventions are similar to open methods. The chest cavity is an optimal site for endoscopic techniques because the thoracic cage allows a large working space once the lung is deflated.

VATS is now becoming the operative technique of choice for most procedures in the chest. Including biopsy and/or resection of intrathoracic tumors, ligation of patent ductus arteriosus, treatment of empyema, and anterior spinal surgery.

Physiologic changes during thoracoscopy

Endoscopic visualization of most intrathoracic sturtures requires significant retractouin or collapse of the ipsilatral lung. This can have signifiacant effects on cardiopulmonary function a through understanding of the dynamic interplay that occurs between the patients hemodynamic stability and the needes for surgical exposure need to be well understood. Single lun ventilation provides when accomplished well with significant atreletisis in the operative chest, provides excellent surgical conditions and significantly reduces the potential for accidental lung injury intra-operatively. Following
partial lung collapse, hypoxic pulmonary vasoconstriction increases pulmonary vascular resistance causing shunt to well-ventilated lung zones. This mechanism decreases ventilation–perfusion mismatch and maintains arterial oxygenation. Hypoxic pulmonary vasoconstriction is obliterated when greater than 70% of the lung is made atelectatic. Volatile anesthetic have also been shown to reduce HPV. The combination of these occurrences can lead to relative desaturations during single lung anesthesia and the fact that young healthy patients can often have more desaturation than patients with chronic lung dz that have more vigorous HPV and more air trapping. What ever lung isolation technique is utilized allowances for intermittent partial re-expansion should be made to safeguard against sustained hypoxemia.

Because carbon dioxide is significantly more diffusible, hypercarbia is less of a problem during single lung ventilation in the absence of significant underlying lung disease. Because effective lung isolation is difficult in pediatric VATS often it is found that one restricts the peak inspiratory pressure in an attempt to reduce operative lung insufflation this can result in hypercarbia due to insufficient alveolar minute ventilation. The physiologic consequence of hypercarbia is significantly less than that of hypoxemia. However persistent respiratory acidosis can led to hyperkalemia and arrhythmia. Hemodynamic instability during single lung ventilation is multifactorial including technique specific factors, mechanical problems and patient specific. The predominating technical factor is the impact of CO2 insufflation. At the beginning of the case CO2 insufflation in the context of a dehydrated NPO patient can potentially precipitate cardiovascular collapse either as the result of tension pneumothorax or from a mediastinal shift causing extra-cardiac tamponade. During the operation lung and/or heart retraction by the surgeon may also precipitate such disturbances. Patient specific factors such as significant thoracic scoliosis, restrictive lung disease, abnormalities of the great vessels and thoracic/mediastinal masses (tumor or loculated fluid collections) can also predispose to hemodynamic instability during positioning, CO2 insufflation and surgery.

Double lung VATS
Lung isolation and often not required for many VATS procedures including lung biopsy tumor resections and decortication procedures. A good working relation with the surgeon can often clarify these instances. At time continuous CO2 insufflation can give excellent operative conditions especially when low airway pressures and short inspiratory times are used. Double lung VATS will often eliminate the respiratory physiologic abnormalities inherent in single lung ventilation techniques however, the hemodynamic abnormalities associated with pneumothorax can be more persistent requiring close monitoring.

Lung isolation techniques
Lung isolation techniques in pediatric VATS include: utilizing a single lumen ETT advanced into the mainstem broncus, a bronchial blocker technique (blocker catheters and univent tubes) and double lumen endobronchial tubes.

The technically simplest technique is utilizing a standard ETT advanced blindly into the mainstem bronchus of the dependant lung. The technique is best accomplished by using auffed ETT ½ size smaller than the expected size for age. Unsufflation of the cuff can then occlude the broncus and allow for isolation. Advancement into the right mainstem bronchus for left sided VATS procedures is straightforward. Due to the high
take off of the right upper lobe bronchus, effective isolation without loss of ventilation to the R upper lobe is facilitated by maintaining the proper orientation of the ETT to ensure ventilation of the RUL via the murpheys eye. Isolation for R sided VATS can be accomplished by advancing the ETT into the Left mainstem bronchus blindly by turning the ETT 90-120 degrees counterclockwise. Extending and rotating the head and neck to the right will often improve successful placement. Alternately the ETT can be advanced over a fiberoptic scope after being placed in the trachea. Unfortunately due to the relationship of the murphy’s eyes to the rotation of the ETT ventilation of the Left upper lobe is more often problematic when using this technique in small children (age under 3) and precise placement is necessary in order to optimize lung isolation. Operative lung atelectasis is facilitated by thorough denitrogenation prior to isolation. This is best accomplished by using 100% oxygen for the 3-5min prior to lung isolation. One method to improve surgical lung deflation is to place a small suction catheter in the mainstem bronchus of the operative lung. The suction catheter is first styletted with an appropriate sized central line J wire then during initial laryngoscopy the catheter is passed thru the vocal cords into mid tracheal position and the patient is then intubated with the appropriate sized ETT. The suction catheter can then be advanced under either flexible bronchoscopic or fluoroscopic guidance into the mainstem bronchus and then the ETT is subsequently advanced into the contralateral mainstem.

Bronchial blocker devices often improve lung isolation over the above described techniques. Blockers such as the Cook products are specifically designed for this purpose and come with a multichannel adapter that allows for straightforward placement on children whose ETT size is greater than 4.5. In younger children the blocker catheter is best placed outside the ETT by the previous described suction catheter method. Other blocker devices (fogerty catheters and pulmonary artery catheters) can be utilized effectively however, they are not as easy to manipulate for accurate consistent placement and there safety is questionable (specifically high pressure ballons with fogarty and lack of the elliptical shape the the Arnt blocker has). Whenever using a blocker one needs to be cognizant of the possibility of dislodgement into the trachea with complete tracheal obstruction that subsequently ensues. This can occur at any time during the procedure and requires deflating the ballon and fiberoptically repositioning the catheter (which can be technically challenging in small infants especially when a forarty or PA catheter is used.

Univent tubes are technically easier to place then a blocker as a result of the fixation of the blocker to a sleeve within the ETT design. Univent tubes do not displace as often during surgical positioning and lung retraction. The main disadvantage to them is the larger outer diameter size that limit their use to children over 4-6 y/o (the smallest Univent is 3.5 which has an outer diameter equivalent to a 5.5-6.0 standard ETT. In older children and young adults when a choice between univent and double lumen tube is considered, univent is easier to place for patients who present difficult to intubate and those who will require post operative ventilation and without exchanging the airway. Univent tubes are more useful than double lumen tubes when left sided surgery is being done whereas the reverse is true.

Double lumen endobronchial tubes offer the greatest degree of flexibility in that one can expand, deflate, cpap or suction either lumen once properly positioned. DLT also rarely dislodge from the placement when the appropriate size is positioned. The
disadvantages are the difficulty in placement and the small working channels for fiberoptic visualization. The smallest size available 26fr can be used in children as young as 8-10yrs. In children, left sided DLT are almost exclusively used due to the variability of the right upper lobe bronchus.

The endoscopic approach to the spine began as a technique for drainage of vertebral abscess and subsequently evolved to include single diskectomy, release of the annulus fibrosis, rib resection for costoplasty, and most recently insertion of correctional implants and fusion.

The primary indications for VATS are in patients that would usually require anterior spinal release surgery. These include rigid idiopathic scoliosis of >75° with side bending correction of <50°, prevention of “crankshaft pneumonia” in the skeletally immature child with >50° curvature, and Kyphotic deformities >70°. Other more uncommon or expanded indication for VATS include; progressive congenital deformity in the chest requiring anterior epiphysieodesis, severe rib hump deformity not corrected by spinal instrumentation, intrathoracic tumors associated with neurofibromatosis and spinal deformity, pseudoarthrosis after anterior intervertebral fusion, progressive spinal deformities in children with neuromuscular or metabolic diseases, resection of rib and intercostal nerve tumors, and excision of the first rib for thoracic outlet syndrome.

Several studies have demonstrated that anterior spinal procedures performed via the VATS method produce similar results to the standard thoracotomy approach. Although the fundamental techniques are the same, modifications of VATS require mastery of new surgical and anesthetic techniques that have their own unique learning curve. In order to perform any variety of VATS it is important that selective lung isolation be achieved. Various techniques for selective lung isolation include; the use of double lumen endotracheal tube, a bronchial blocker, or the univent endotracheal tube. Selective lung ventilation in pediatrics must be individualized based upon the patient’s age, size, and the site of surgery. During VATS for spinal surgery the operative site is typically on the convex side of the spinal curve. As a result, the more restricted lung will require isolation and ventilation. The challenge of maintaining oxygenation and ventilation in the compromised lung is further complicated by the difficulty encountered in properly positioning the airway catheter in these patients with contorted tracheobronchial anatomy. As a result the time required by the anesthesiologist to obtain selective lung ventilation is variable (15-60min in one study). A thorough preoperative evaluation of the airway including, physical examination to identify difficulty with intubation as well as evaluation of the chest x-ray, CT scan and identification of the operative site is required. Conformation of selective lung ventilation by fiberoptic techniques can be difficult in small children. The use of fluoroscopy should be considered as a non-invasive quick method of verifying proper placement of the airway catheter as well as a means of verifying proper lung deflation and inflation. If a passive deflation technique is utilized (bronchial blocker) full deflation of the lung may take 10-15 min and thus should be implemented well before placement of the thoracic portals. The thorascopic portals are placed in various arrays according to surgeon preference and operative site. The first portal should be placed above the T7 interspace to avoid injury to the diaphragm. Care must be taken to avoid injury to the lung during placement of the first portal by digitally examining the chest cavity prior to introduction of the
thoracoscope. After confirming deflation of the lung, additional portals are placed under thorascopic visualization and hemostasis is obtained. A rigid thoracoportal is often necessary for the thoracoscope to avoid damage to the fiberoptics. Rigid portals are the main cause of post-op intercostal neuralgia, which has been reported to persist for many months in some patients⁵. As the surgeon gains more experience with proper positioning and technique, the incidence of this complication typically diminishes. By rotating the patient anteriorly and placing the patient into trendelenburg for the lower thoracic spine or reverse trendelenburg for the upper thoracic spine, the lung usually falls away from the operative field when completely collapsed. Retraction of the lung may be necessary especially when the lung is not fully deflated or when operating below T9-10 as a result of the diaphragm. Retraction of the lung can be performed by the use of a fan shaped retractor. The vertebral column is approached through the parietal pleura, which is divided and stripped. The segmental vessels are thus exposed. Multi-level anterior diskektomies are necessary for correction of most scoliosis procedures and usually requires diskektomy at six to eight levels⁶. With proper placement of thoraco-portals, it is possible to safely excise disk contents at levels between T2-3 to L2 although lower levels require longitudinally splitting the diaphragm and subsequent repair⁷. Controversy arises whether segmental vessels should be ligated to allow for better exposure or whether they should be preserved. In a large retrospective review by Winter et al of scoliosis surgery at one institution, 1197 procedures in which more than 6000 vessel levels were cross-ligated failed to cause a neurological complication⁸. The greater splanchnic nerve sympathetic chain is usually transected at one or more levels during anterior diskektomy. The parents and child should be made aware that there is a possibility of hot and cold phenomena (sympathetic release) in the contralateral/ipsilateral lower extremity. This condition usually resolves over a 6-month period³.

Contraindications to VATS are: (1) inability to tolerate single lung ventilation (hypoplastic contralateral lung) (2) severe acute respiratory insufficiency, (3) high airway pressures with positive pressure ventilation, (4) pleural symphysis, (5) empyema, and previous thoracotomy and thoracostomy. Patients with severe scoliosis, particularly neuromuscular scoliosis and very young children present additional challenges and should be attempted only after successful initial experience has been gained³. Younger patients also have more vascurized bone posing more of challenge to establishing hemostasis thorascopically. As the magnitude of the scoliosis increases, the distance between the anterior spine and the lateral chest wall decreases making access to the spine more difficult and requires more portals.

Many complications associated with open thoracotomy for anterior spinal surgery are also possible during VATS including; bleeding, lung trauma, dural tear, lymphatic injury, spinal cord injury, sympathectomy presenting as temperature and skin color changes below the level of injury. Tension pneumothorax in the ventilated lung can result from barotrauma. The anesthesiologist must be aware that during anterior spinal instrumentation a steinmann pin may be advanced into the down lung resulting in tension pneumothorax. All complications pertinent to the specific technique of single lung ventilation including injury to the vocal cords, bleeding in the airway and rupture of the membranous portion of the tracheo-broncheal tree can occur. Pleural adhesions should be anticipated in patients with neuromuscular scoliosis as well as in patients with prior
history of pneumonia, empyema, or previous thoracotomy and may lead to excessive bleeding and injury to the lung parenchyma. Anticonvulsants particularly carbamazepine increase the likelihood of bleeding. Thoracic insufflation to collapse the isolated lung should be avoided (especially greater than 10 mm Hg) as it can lead to sudden mediastinal shift with a precipitous fall in cardiac output or cardiac tamponade and subsequent cardiovascular collapse. Insufflation can also lead CO2 embolism with fatal cardiac and neurological sequella. Complications associated with placement of access ports include injury to the intercostal nerve, vein, or artery. And rigid thoracic ports increase the likelihood of post-op intercostals neuralgic pain syndrome. Complications related to manipulation of endoscopic instruments include; injuries to thoracic structures leading to air leak or bleeding, intrathoracic burns from the high intensity illumination, fragmentation of instruments in the chest cavity, and the potential for fire or explosion when uni-polar cautery is used in the presence of high inspiratory oxygen concentrations.

The benefits of VATS include reduced operative time once the surgery team has learned the technique and reduction in postoperative pain. The length of ICU stay has decreased from several days to 24 hr in most cases. Decreased overall blood loss and less chest tube drainage have been reported in uncontrolled retrospective reports. Other benefits of VATS include; earlier discontinuation of the chest tube, improvement of postoperative respiratory function, quicker rehabilitation of the shoulder and better cosmetic outcome with smaller surgical incisions. These benefits increase patient satisfaction, and may decrease hospital costs due to shorter ICU stays and total hospital days undergoing convalescence.