Anaesthesia for Pediatric Video Assisted Thoracoscopic Surgery

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Video assisted thoracoscopic surgery (VATS); a minimally invasive (keyhole) surgical procedure allows the surgeon to directly examine the inside of thoracic cavity without a big incision and thereby avoids extensive damage to the chest wall. Thoracoscopy was first introduced by Jacobaeus in 1910 for the diagnosis and treatment of tuberculosis.[1,2] Recent advances in video assisted thoracoscopy have stimulated a more aggressive approach to endoscopic thoracic surgical intervention, even in children.

Visualization of intrathoracic structures requires a partially or totally collapsed ipsilateral lung and can be performed by one-lung ventilation (OLV) or less commonly, two-lung ventilation in combination with CO_2 Insufflation (Capnothorax). OLV along with the creation of an artificial pneumothorax causes absorption of CO_2 by the pleural surface and there is also a potential for inadvertent CO_2 embolism. All these can have significant adverse effects on the cardiopulmonary physiology which can aggravate the pathophysiological changes already present due to the existing disease process.[4]

This approach offers the advantages of a smaller incision, less postoperative pain and a faster postoperative recovery as compared with thoracotomy.[3] A thorough knowledge of the associated pathophysiological changes, appropriate monitoring and good planning allows the safe provision of anesthesia for these procedures and this is based on the expertise in the fields of both pediatric and thoracic anaesthesia.

Indications: Indications in children include biopsy or excision of mediastinal masses, biopsy of pulmonary infiltrates, decortication of empyema thoracis, recurrent pneumothorax, bronchogenic cysts, PDA ligation, thymectomy, Heller's myotomy and CDH repair. With the improvement in the equipment, these techniques are being applied to younger children, even in neonates and infants as young as with a mean age of 3.0±3.8 years and mean weight of 10.7±8.0 kg.[5,6] Preoperative evaluation

Patients presenting for thoracoscopic surgery should undergo a similar preoperative evaluation to those presenting for open thoracotomy with special stress on the degree of pulmonary and cardiac dysfunction. It is customary to obtain a complete history and physical examination. The preoperative examination should also attempt to identify previously undiagnosed illness in the otherwise healthy patient without signs of problems, such as an unrecognized congenital heart defect, airway compromise with an abnormal airway or extrinsic tracheal compression which may place the patient at an increased risk during anaesthesia.

Preoperative laboratory evaluation includes routine investigations and a chest X-ray. Additional preoperative evaluations like pulmonary function test (PFT) and ECG are not routinely indicated but rather obtained based on the patients' medical history and associated underlying illness. Specific investigation like CT scan of the chest is useful in children with an anterior mediastinal mass. Compression of greater than 50% of the cross sectional area of the trachea on CT imaging used to identify the high risk population for general anesthesia[7] Decision regarding cardiopulmonary bypass, backup measure depends on preoperative radiation/ chemotherapy, to shrink the mass and detrimental mass effect is important before administering general anesthesia.

Preoperative echocardiography is suggested to rule out cardiac compression by the tumour mass or the presence of a congenital cardiac defect. Inspiratory and expiratory flow volume loops may provide useful information concerning the site of obstruction in older children.

Premedication and Optimization: Chest physiotherapy, good nutrition, bronchodilator/antibiotic therapy, steroid supplementation, hydration etc. helps in optimizing the patients' condition prior to surgery. In an otherwise healthy patient without any signs of airway compromise, oral premedication with trichloryl (75 mg kg^{-1}) administered 30 to 45 minutes prior to induction or intranasal midazolam 0.3 mg kg^{-1} provides anxiolysis, allows easy separation from parents and acceptance of a face mask. Older children can be premedicated with Diazepam 0.1-0.2mg kg^{-1} orally 1 hour prior to procedure.

Blood should be kept in reserve, as there is always a possibility of conversion to open thoracotomy.

Conduct of general anaesthetic for pediatric VATS

Induction and monitoring

The goals of anaesthesia induction includes minimizing airway reactivity, optimizing gas exchange, maintaining

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stable cardiovascular function and preventing ventilatory depression in spontaneously maintained patients. The anesthetic and surgical plan must be discussed with the surgeon, nursing and technical personnel in the operating room.

Anaesthetic induction techniques include inhalation induction with inhalation anesthetics like sevoflurane and oxygen, or by intravenous agents and this can be followed by the administration of a nondepolarizing neuromuscular blocking agent's vecuronium, atracurium, depending on the proposed length of the procedure.

Blood loss during a diagnostic thoracoscopy is usually minimal. It is however advisable to have preferably two venous accesses prior to the start of the procedure as inadvertent injury by one of the trocars and/or the endoscopic instruments may occur. In patients with normal cardiovascular function, routine monitoring of the central venous pressure offers little to improve or influence anesthetic care. Central venous access is generally reserved for cases in which adequate peripheral intravenous access is unavailable. If central venous access becomes necessary, internal jugular or subclavian vein cannulation on the side of thoracoscopy is recommended to avoid the possibility of bilateral pneumothoraces, the intentional pneumothorax induced on the side of the thoracoscopy and the unintentional pneumothorax as a complication of the central venous access procedure.

Standard intraoperative monitoring as suggested by the American Society of Anesthesiologists includes continuous electrocardiogram, automated noninvasive blood pressure monitoring, pulse oximetry, an esophageal stethoscope, continuous monitoring of temperature, and end tidal CO_2 ($EtCO_2$) measurement. As the latter may be inaccurate during thoracoscopy procedures, especially during one lung ventilation due to alterations in dead space and shunt fraction, another useful technique is the use of a precordial stethoscope applied to each hemithorax which allows independent auscultation of each lung field.

Special monitoring like intra arterial blood pressure monitoring is not routinely used unless indicated by the clinical status of the patient

In specific cases with an anterior mediastinal mass, in the event of respiratory obstruction after induction of anaesthesia, the introduction of a rigid bronchoscope into the trachea may be lifesaving.

The most important requirement is vigilant monitoring as one encounter arrhythmias, mediastinal shift, hypertension or hypotension, hypoxemia, hypercarbia, impaired hypoxic pulmonary vasoconstriction. It is difficult to assess the blood loss during thoracoscopy[1] and prudent awareness of the possibility of some major vessel injury and torrential bleed should be anticipated.

Intraoperative anaesthetic care

Fentanyl in doses of 1-5 mcg kg^{-1} to provide analgesia and anesthesia can be maintained either by using inhalational agents or Propofol infusion. Ventilation is controlled by using short acting muscle relaxants.

Video assisted thoracoscopic surgery (VATS) is performed in the upright and lateral decubitus positions, which cause mismatch in ventilation to perfusion ratio (V/Q) after general anaesthesia. The V/Q mismatch is more in smaller children, especially in the lateral decubitus position, because their compliant chest makes the functional residual capacity come close to the residual and closing volumes and hence they are prone to develop atelectasis. General anesthesia, neuromuscular blockade and mechanical ventilation further increase this V/Q mismatch. Inhalational anesthetics impair hypoxic pulmonary vasoconstriction (HPV) and neuromuscular blockade decreases functional residual capacity (FRC) and these make the child more prone to develop atelectasis. The oxygen consumption in infancy is about 6 to 8 ml $kg^{-1}min^{-1}$ which are about twice that of an adult. Therefore infants are at increased risk for rapid and profound desaturation during thoracic surgery.[1,2,8,9,10,12]

Anaesthetic technique for thoracoscopy[1,2,5,9]

In children above 8 years of age or weight more than 30-35 kg can be managed using most of the techniques which are done as in adults. Special techniques to isolate the operative lung are suitable in smaller children. OLV may be difficult in infants and small children, because endobronchial intubation with a single lumen to achieve OLV often blocks the right upper lobe of the intubated lung because of the close proximity of the right upper lobe bronchus to the carina.

The various anesthetic techniques are:

A. Local anaesthesia
B. Regional anaesthetic techniques
C. General anaesthesia with OLV
D. General anaesthesia with two lung ventilation in combination with CO2 insufflation (Capnothorax)

A. Local anaesthesia may be possible in older adolescents where the lateral chest wall and parietal pleura are infiltrated with a local anaesthetic for trocar placement.

B. Regional anaesthetic techniques include thoracic epidural anaesthesia, thoracic paravertebral blockade, multiple intercostal blocks and interpleural analgesia. Regional anaesthesia techniques and local anesthesia with sedation offer the advantage of maintaining spontaneous ventilation and interfere less with surgical exposure. However patients with significant pulmonary disease are unable to compensate for the temporary loss of pulmonary surface area due to partial collapse of the lung on the side of the thoracoscopy. This technique is usually reserved for very brief procedures.

C. General anaesthesia and OLV: With general anesthesia and IPPV, intrathoracic visualization and surgical access may be impaired due to lung movement. To overcome this problem thoracoscopy is performed using techniques to isolate the lung and provide one-lung anaesthesia. Like in adults, OLV can be managed with a double lumen tracheal tube (DLT) but the smallest available DLT is size 28F which is suitable in patients whose weight is 30-35 kg. This allows the lung on the operative side to be collapsed and motionless, facilitating exposure and surgical instrumentation, while gas exchange (oxygenation and CO_2 elimination) is maintained by ventilating the non-operative dependant lung.

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1. Selective mainstem intubation
2. Double lumen endotracheal tube
3. Bronchial blockers
4. Univent endotracheal tube.

1. Selective main stem intubation:

The simplest method to provide OLV is to intubate the contra-lateral main stem bronchus with a conventional single-lumen endotracheal tube (ETT). The ETT is advanced until breath sounds on the operative side disappear and this can be achieved very quickly. Successful placement of the tracheal tube into the desired bronchus may be difficult in smaller patients and bronchoscopic guidance or fluoroscopy can aid correct placement. It is recommended to use a cuffed ETT in patients more than two years of age to prevent inadvertent ventilation of the operative side and to prevent soilage of the nonoperative lung.

Potential problems with main stem intubation:

- Inadequate seal of the nonoperative bronchus.
- Inadequate lung collapse.
- "Spill over" of secretions to the good lung.
- Does not allow suctioning of the soiled lung.
- Cannot use continuous positive airway pressure (CPAP).

2. Double lumen tube:

It suitable in patients less than 30 to 35 kg because the smallest, commonly available DLT is size 28F. DLT allows suctioning, administration of continuous positive-airways have pressure (CPAP) or oxygen insufflation to the non-operative lung. DLT insertion in children is like in adults and care must be taken to avoid trauma to the larynx, carina and bronchus. Fiberoptic bronchoscope should be used to confirm placement. The tracheal and bronchial cuffs are high-volume, low-pressure cuffs, hence care must be taken to avoid over inflation and damage to the respiratory mucosa.

3. Bronchial Blockers:

The pediatric bronchial blocker is a useful tool for achieving lung isolation in children and allows better surgical exposure. Commonly used bronchial blockers are Fogarty embolectomy catheter, Swan-Ganz catheter and Arndt bronchial blocker. These devices have a balloon at the end that is inflated to occlude the main bronchus of the operative lung and they are placed under direct vision with a fibreoptic bronchoscope.

Problems with bronchial blockers:

- Dislodgement of the blocker balloon into the trachea.
- Slow collapse of the operated lung.
- High pressure cuff can damage or even rupture the airway.
- Suction of the operative lung is not possible.
- Continuous positive airway pressure (CPAP) cannot be applied to the operated lung.

4. Univent tube

The Univent tube, made in Japan is a conventional ETT with a second lumen containing a small hollow non latex bronchial blocker that can be extended about 8-10 cm beyond the tip and when the ballon is inflated, it serves as a blocker. It is placed in the same manner as a standard tracheal tube and when one-lung ventilation is required, the bronchial blocker is advanced into the main stem bronchus of the operative lung under direct vision with a flexible fibreoptic bronchoscope

Advantages of Univent tube:

- Ease of placement.
- Ability to change intermittently from one to two-lung ventilation.
- Channel through the bronchial blocker permits oxygen insufflation into the operative lung.
- In case of postoperative ventilation the bronchial blocker can be removed and the Univent tube can be left in place like a standard ETT.
- Allows suctioning.

The Univent is supplied in sizes 3.5-9.0 mm internal diameter and the smallest size available is 3.5mm and 4.0 mm. The 3.5mm size has an outer diameter of 7.5-8.0mm which is equivalent to a standard 5.5-6.0mm ETT tube thereby limiting its use in patients older than four to six years of age due to the risk of postoperative subglottic stenosis.

D. General anesthesia with two lung ventilation in combination with CO2 insufflation (Capnothorax).

CO2 insufflation into the operative hemithorax is particularly useful in smaller children where lung isolation is not possible. While performing capnothorax, the insufflations pressures should be maintained between 4 - 6 mmHg and CO2 flow limited to 1 l/min1. The consequence of a higher flow and increased pressure results in sudden mediastinal shift and cardiovascular collapse.[12,13,14,15,16]

However because of increased thoracic distensibility in children, the reduction in lung compliance and increase in peak airway pressure following capnothorax are less intense as compared to those seen in adults. The continuous insufflation of large volumes of cold, non humidified CO_2 into the thoracic cavity causes hypothermia in these small children. When the procedure is long, hypercapnia can develop which will require increased minute ventilation in order to restore $ETCO_2$ to baseline values.

Maintenance[1,2,7]

Once successful separation of the non-operative and operative lung has been accomplished, anaesthesia is maintained with a combination of intravenous and inhalational anaesthetics. Isoflurane 0.5-1.0 MAC preserves hypoxic pulmonary vasoconstriction (HPV) than halothane and enflurane. HPV maintains oxygenation during OLV by restricting pulmonary blood flow to the non-ventilated lung. Intra venous agents such as fentanyl, ketamine, benzodiazapines, and barbiturates have been shown to have little or no effect on HPV. Agents that can interfere with HPV, increase shunt fraction and impair oxygenation during OLV are the direct acting vasodilators, aminophylline and beta adrenergic agonists such as albuterol.

The following methods are used to improve oxygenation.

- Increase FiO2
- Tidal volume - 8-12 ml/kg to the ventilated lung to prevents atelectasis
- If airway pressure if high, tidal volume may be decreased and respiratory rate increased.
- CPAP to the operative lung.
- PEEP to the ventilated lung.
- High frequency jet ventilation at low driving pressures 10-12 psi to the operative lung.
- Ipsilateral pulmonary artery can be clamped.
- Re-inflation of non-ventilated lung (prophylactically every 5 minutes).
- To maintain cardiac output.

Intraoperative fluid management:[18]

Fluid administration during thoracoscopic surgery should be done judiciously because excessive administration of intravenous fluids can cause increased shunting and subsequently lead to pulmonary edema of the dependent lung, particularly during prolonged surgery. Intravenous fluids are administered to replace volume deficits and for maintenance and "third space" loss should not be replaced. The common dictum is "Don't drown the down lung". The fluid of choice is compound sodium lactate solution (Hartmann's solution) with or without dextrose.

Reversal and extubation

It is possible that any structure the surgeon manipulates may be damaged during the procedure, so it is important to have a functional chest tube with underwater seal drainage so that extubation can be performed safely. Bilateral air entry should be checked at the end of anesthesia and postoperatively chest X- ray is done to confirm lung expansion.

Complications of VATS:[19,20]

- Subcutaneous emphysema, residual or recurrent pneumothorax due to persistent air leak.
- Down Lung syndrome.
- Gas embolism.
- Local wound infection, pulmonary abscess or empyema.
- Lung herniation through the chest wall.
- Dissemination of malignant disease.
- Horner syndrome.

Post-operative pain control[21,22]

Thoracoscopic procedures offer the advantage of small incisions without either splitting of the serratus anterior or latissimus dorsi muscles or spreading of the ribs, two techniques which markedly contribute to postoperative pain. Children who underwent VATS also require less postoperative analgesia than those who had an open thoracotomy.

1. Oral: Nonsteroidal anti-inflammatory drugs, Paracetamol etc
2. Rectal suppositories: Paracetamol and diclofenac provide long lasting analgesia and reduce opioid requirements.
3. Intravenous route: IV opiods via PCA pump for the first 24 hours using morphine or fentanyl provide satisfactory analgesia especially in older children.
4. Intercostal nerve blocks or intrapleural installation of 0.25% bupivacaine relieves pain from chest tubes or instrument insertion points.

CONCLUSION

A video assisted thoracoscopic surgery procedure has numerous advantages as compared to open thoracotomy. These include lesser pain, smaller incisional scars and shorter hospitalization. It is important for the anesthesiologist to have a clear understanding of the physiologic changes and potential complications which can happen so as to perform VATS safely. A good communication between the anesthesiologist and the surgeon adds safety to the surgery.

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