THORACIC ANAESTHESIA

Dr. Paul Forrest

This discussion is not intended to be a comprehensive review of the topic, instead I have attempted to distil as much as possible the pertinent clinical considerations. Of the standard texts, I found the chapter by Jay Brodsky (1) to be a concise and clinically useful summary of the topic. I will (briefly!) review the relevant anatomy and physiology, then move onto preoperative assessment, airway management, intra- and postoperative management and finally consider some specific clinical problems.

ANATOMY

An understanding of thoracic and airway anatomy is important for several reasons. It provides the clinical basis for the successful application of fibreoptic bronchoscopy and regional anaesthesia. In addition, it is important to understand the surgical pathology and the procedure proposed as this may help predict likely intraoperative problems.

I will only briefly review the bronchoscopic anatomy:

The adult trachea is about 15cm long, it extends from the lower end of the cricoid cartilage at C6 and divides at T5. The tracheal diameter is roughly the same as that of the patient's index finger. It is C- shaped anteriorly due to the presence of 16-20 cartilages joined posteriorly by fibroelastic tissue and trachealis muscle. By comparison, the mainstem bronchi are circular. The right main bronchus is wider and shorter than the left, it gives off its upper lobe bronchus at 2cm as opposed to 5cm on the left. The right main bronchus arises at 25 to the vertical compared with 45 on the left. Therefore inhaled foreign bodies and endotracheal tubes are more likely to enter the right lung and left-sided double lumen tubes are preferred to right-sided as they have a lower risk of impairing upper lobe ventilation. There are 3 lobes and 10 bronchopulmonary segments in the right lung, 2 lobes and 8 segments on the left.

PHYSIOLOGY

Lateral Position / Closed Chest

The perfusion of the dependent lung is greater than the nondependent lung due to the effects of gravity. The converse applies for the distribution of ventilation between the lungs during IPPV, these changes result in an increase in V/Q mismatch and shunt.

Lateral Position / Open Chest

The compliance of the nondependent lung increases as it is less restricted by the chest wall. Normally, the distribution of perfusion is not greatly affected. However, if there is a large increase in the compliance of the nondependent lung and subsequent fall in airway pressure in that lung, perfusion to the nondependent lung may be increased.

The increase in the compliance of the nondependent lung leads to an increase in the share of the ventilation directed to that lung. This may lead to worsening V/Q mismatch and shunt.

The dependent lung will be poorly ventilated and well perfused, leading to shunt- which will be exacerbated by compression of the lung by the mediastinum and the diaphragm / abdominal contents.

One Lung Ventilation

When one- lung ventilation is instituted, there persists some perfusion to the nondependent lung, producing an obligatory shunt of 20-30%. This leads to a reduction in PaO_2, $PaCO_2$ is little affected provided ventilation is maintained constant. The major determinants of blood flow to the nondependent lung are gravity, surgical interference (eg. clamping the pulmonary artery during pneumonectomy), the presence of lung disease and hypoxic pulmonary vasoconstriction (HPV).

In the dependent lung, blood flow is determined by gravity, lung disease, the ventilation method and HPV. The mode of ventilation is important: a reduction in tidal volume during one lung ventilation resulting in airway collapse will increase shunt. Hyperventilation of the dependent lung may produce inhibition of HPV, resulting in blood diversion to poorly oxygenated areas. Excessively high airway pressures will result in an increase in pulmonary vascular resistance of the ventilated lung, leading to diversion of blood to the nonventilated lung.

Hypoxic pulmonary vasoconstriction

HPV defends arterial oxygenation by diverting blood flow away from poorly ventilated areas of lung. Typically this occurs in areas of atalectasis or low V/Q ratio. HPV may be inhibited by vasodilator drugs such as nitroprusside, nitroglycerine, calcium channel blockers and ß2 agonists. The HPV response is maximal at normal pulmonary artery pressures and decreased at both high and low pulmonary artery pressure. Both high and low PvO_2 conditions inhibit HPV. A low PvO_2 causes HPV to occur in normoxic alveoli, diverting flow away from those alveoli. This is why a reduction in cardiac output during one lung ventilation may result in severe hypoxia.

HPV is also inhibited by hypocapnia and enhanced by hypercapnia.

PRE-OPERATIVE ASSESSMENT

The majority of cases presenting for thoracic surgery have lung or bronchial carcinoma, mediastinal masses or oesophageal disease. The patients are usually elderly, with a long history of smoking and consequent comorbid pathology. The focus of the preoperative assessment is an assessment of the patient's cardiorespiratory function. General principles about the need for preoperative optimisation of the patient apply, the presence of active infection / wheeze should be identified and treated if possible, however, in some patients this may be related to pulmonary malignancy and may not be amenable to treatment prior to surgery.

Most surgeons will not operate on patients who are actively smoking.

Routine Investigations

Full blood count may reveal polycythaemia due to smoking or a raised white cell count due to active infection.

Chest X-ray may reveal areas of consolidation / collapse or the presence of a pleural effusion. All of these conditions will worsen intrapulmonary shunt.

Arterial blood gases may reveal CO2 retention in chronic bronchitics. A PaCO2 of >50mmHg and /or a PaO2 of <60mmHg is associated with an increased risk of postoperative pulmonary complications.

Assessing patients for lobectomy / pneumonectomy

Despite a number of algorithms that have been devised for determining a patient's ability to tolerate lung resection, in most centres this is a clinical evaluation supplemented by basic investigations such as spirometry and arterial blood gases. The single most important clinical indicator sought is the patient's exercise tolerance, if a patient can't walk up a flight of stairs without stopping they are unlikely to be considered for pneumonectomy.

Patients who are scheduled for lobectomy should be assessed as for pneumonectomy as occasionally a more extensive operation is performed than was initially planned.

Spirometry

Spirometry should be performed on all patients undergoing lung resection. Provided the patient effort is adequate, the presence and severity of obstructive and restrictive lung disease can be reliably identified.

The following parameters have been associated with an increased risk of pulmonary complications following pneumonectomy:

FVC <50% of predicted or <1.75-2L

FEV1>2L, mortality = 10%, <2L, mortality = 20-45%

MBC <50-60% of predicted, mortality = 5-32%

An FEV1 of less than 800ml generally precludes thoracic resection apart from lung volume reduction surgery

The response to bronchodilators should be assessed in patients with obstructive airways disease.

Split lung function tests

Patients who fail the spirometric criteria for operability are in some institutions considered for split function lung studies.

Ventilation and Perfusion Lung Scanning

Perfusion lung scanning with radioactive isotopes can be used to estimate the relative blood flow to each lung. If the predicted postoperative FEV1 is > 800ml a patient may be considered for pneumonectomy. For example, a patient has a preoperative FEV1 of 2.0L and the uninvolved side accepts 55% of the blood flow, the predicted postoperative FEV1 would be 1.1L.

Unilateral Pulmonary Artery Occlusion

If the predicted FEV1 is < 800ml, a “functional pneumonectomy” can be performed by testing the patient’s response to balloon occlusion of the operative lung’s pulmonary artery. Patients are excluded from pneumonectomy if the mean pulmonary artery pressure exceeds 35mmHg or the PaO2 falls below 45mmHg.

These techniques are invasive and expensive and not widely used.

PRE-OPERATIVE PREPARATION

The perioperative events need to be explained to the patient. In particular, details of their pain management need to be discussed preoperatively. Patients who receive either PCA or thoracic epidurals need the appropriate explanations of their benefits and risks.

Premedication should be light, particularly in patients who are most at risk for hypoxia due respiratory depression. The use of atropine may be of some clinical benefit as a bronchodilator but will produce patient discomfort from a dry mouth and may result in delayed recovery in elderly patients.

Preoperative respiratory preparation that should have been performed are:

1. Cessation of smoking at least 4 weeks preoperatively
2. Appropriate treatment for bronchospasm and respiratory infections
3. Physiotherapy education regarding breathing exercises / incentive spirometry postoperatively.
4. Blood should be taken for Type and Screen for patients undergoing lung resection.

PREINDUCTION

A large-bore cannula is essential for most procedures as unexpected blood loss may occur.

Standard monitoring should include ECG, NIBP, SaO2, CO2 and anaesthetic agent analysis. Invasive blood pressure monitoring is useful when repeated blood gas analysis may be necessary, such as following pneumonectomy. CVP or PA catheters are of limited use intraoperatively as fluid volume shifts are usually not large and the values recorded may be difficult to interpret due to the effects of the lateral position and lung collapse. However, they may be of more use for postoperative fluid management, particularly following pneumonectomy where it is essential to avoid fluid overload.

ANAESTHETIC TECHNIQUE

The ideal thoracic anaesthetic technique would be rapid in onset and offset and produce inhibition of airway reflexes and bronchodilation It would allow the use of a high FiO2 without inhibiting hypoxic pulmonary vasoconstriction. It would also produce no adverse cardiovascular effects.A balanced anaesthetic technique using a volatile agent using a volatile agent with or without nitrous oxide, an opiate and a short-intermediate acting muscle relaxant will achieve most of these goals. All of the volatile agents have been shown to inhibit HPV in vitro, however, their effects on HPV in vivo are complicated by their cardiovascular actions and are probably relatively minor.

ONE LUNG VENTILATION

Indications

The indications for double- lumen tube intubations are mainly relative as most thoracic procedures can be performed with a single-lumen tube. The only absolute indications are:

1. To prevent cross-contamination of a non-involved lung from blood or pus.
2. To control the distribution of ventilation in cases where there is a major air leak : such as bronchopleural fistula, tracheobronchial trauma, or in major airway surgery.
3. To perform bronchopulmonary lavage.

The relative indications may be subdivided into high and low priority, high priority indications are procedures such as thoracic aneurysm repair, pneumonectomy and upper lobectomy. Lower priority indications include middle and lower lobectomy, oesophagectomy, thoracoscopy and thoracic spinal procedures.

Double lumen tubes / bronchial blockers

There are a variety of double-lumen tubes available. The Carlens red rubber tube was the first to be used for one lung ventilation. It has a carinal hook to aid placement and it is reusable. It is still used in some institutions because it very reliably produces lung separation although it may be associated with a higher risk of airway trauma (due to high-pressure cuffs).

Modern double lumen tubes such as the Bronchocath have low-pressure, high volume cuffs. They are transparent, with a coloured endobronchial cuff for ease of bronchoscopic recognition. Right-sided double lumen tubes are available that have a slot for ventilation of the right upper lobe, however, left-sided tubes provide more reliable ventilation and may be used for the vast majority of cases, including left pneumonectomy- where the bronchial lumen may be withdrawn into the trachea (if necessaray) prior to dividing the left main stem bronchus.

Successful separation of ventilation can be confirmed by auscultating each lung while clamping and unclamping the connector to each lumen. Bronchoscopy can also be used to confirm tube position although this is usually unnecessary routinely. It is important to reconfirm that lung separation can be performed following lateral positioning of the patient as the tube may have moved.

The sizes of double-lumen tubes available ranges from 26-41Fr. The largest tube possible should be placed as the cuff pressure necessary to obtain a seal is reduced and hence there is less potential for airway trauma and cuff herniation. For males, the usual size required is 39 or 41 Fr, for females 37 or 39Fr. For children of < 30kg. a bronchial blocker may be used either separately or incorporated into the wall of a single-lumen tube, such as the Univent tube.

It is worth remembering that in an emergency situation such as in unilateral pulmonary haemorrhage, one-lung ventilation can be achieved by advancing a single-lumen tube into the bronchus of the unaffected side.

The most common complication of double-lumen tube intubation is malposition of the tube. Traumatic laryngitis can occur, as can tracheobronchial tree disruption. The endobronchial tube has the potential to become involved in the surgical field in proximal airway surgery or during pneumonectomy.

Maintaining oxygenation

Minute ventilation should be maintained constant during one lung ventilation (OLV), provided that excessive ariwaty pressures do not result. Peak inspiratory pressures above 40cmH2O have been independently associated with post pneumonectomy pulmonary oedema (2). There is evidence that the old recommendation to maintain the same tidal volume as for two-lung ventilation may lead to lung injury (3). Current recommendations are that the peak inspired pressure should be < 35cmH2O, with a plateau pressure of less than 25cmH2O. The FiO2 may be increased to 1.0 if necessary to preserve oxygenation, concerns about the potential for absorption atalectasis are probably not clinically relevant. Should hypoxia occur, the tube position needs to be checked immediately. Tube patency also needs to be confirmed and bronchospasm excluded. Should hypoxia persist, it may be necessary to intermittently reinflate the operative lung. Other manoeuvres that may be useful are to apply 2-5cmH2O of CPAP with 100% oxygen to the operative lung (following lung re-expansion) (4,5). Applying PEEP to the dependent lung is probably helpful only in younger, healthier patients, as elderly patients tend to already have a degree of auto-PEEP. Combining PEEP to the ventilated lung with CPAP to the operative lung will probably not be more effective than CPAP alone. During pneumonectomy, ligation of the pulmonary artery will eliminate the shunt through the operative lung.

Lung reinflation

Following OLV, lung reinflation using high sustained manual CPAP pressures (30-40cmH2O) will be necessary to expand areas of atalectasis. Sustained manual CPAP is also used to check for air leaks following lobectomy and pneumonectomy,

Unilateral pulmonary oedema occasionally develops after reinflation of the lung This is most likely after reinflation following a prolonged period of collapse (eg. following drainage of a large pleural effusion) or if there have been repeated episodes of lung collapse / reinflation.

Prolonged positive pressure ventilation will stress the bronchial suture lines following lung resection which will worsen air leak, hence early return to spontaneous ventilation and extubation is desirable.

Suction

Endobronchial and endotracheal suction may need to be performed frequently in patients with bleeding lungs or with copious secretions or pus. It should be performed prior to re-expansion of a collapsed lung. Complications of suctioning include hypoxia and arrhythmias.

PATIENT POSITIONING

For thoracotomy, the patient is normally positioned fully lateral and the patient must be adequately secured to the operating table. It is important to ensure that lung separation is still possible and that iv. lines and monitors are accessible.

POSTOPERATIVE CONSIDERATIONS

Complications

i. *Atalectasis:* Atalectasis is the commonest pulmonary complication following thoracotomy. It may be due to incomplete reinflation of the operative lung following one- lung ventilation or it may be due to bronchial obstruction by secretions. If unresolved, pneumonia may develop. Treatment includes effective analgesia (to prevent hypoventilation due to pain), coughing and breathing exercises such as incentive spirometry.

ii. *Pneumothorax:* A pneumothorax can still occur in the presence of a pleural drain if there is a bronchopleural communication and the chest drain becomes occluded (eg. blood or kink) or there is a malfunction with the underwater seal drain apparatus. This may progress to a tension pneumothorax, especially if the patient is being ventilated with IPPV or PEEP.

iii. *Cardiac Herniation:* If the pericardium has been disrupted following pneumonectomy, herniation of the heart may occur through the defect. Acute angulation of the heart and great vessels may produce arrhythmias or severe hypotension in the presence of high filling pressures.The patient should be immediately turned with the non-operative lung dependent. If the chest drain on the operative side had mistakenly put on suction, it should be opened to air. Immediate reoperation may be required.

iv. *Haemorrhage:* Major haemorrhage is usually obvious, apart from the haemodynamic signs, excessive chest tube drainage will be seen, provided that the drains are not obstructed by blood clot.

v. *Arrhythmias:* Atrial arrhythmias may occur after any lung resection, but are most common after pneumonectomy. Prophylactic digitalisation is still widely carried out for patients undergoing pneumonectomy although there is little evidence to support its efficacy. Calcium channel blockers may be more effective as prophylaxis.

vi. *Right heart failure:* Extensive lung resection may lead to right heart failure by increasing the pulmonary vascular resistance. Treatment options include IPPV (to reverse hypoxia and hypercapnia inducing aggravations of HPV), dobutamine, phosphodiesterase inhibitors, nitroglycerine and inhaled nitric oxide.

Fluid Management

Following lung resection, there is an increased potential for pulmonary oedema to develop. Right pneumonectomy is associated with the highest risk of this complication -which is associated with a high mortality.

Pulmonary oedema may develop due to several factors. Following pneumonectomy, the entire pulmonary blood flow is directed into the remaining lung, raising pulmonary vessel hydrostatic pressures. In addition, loss of lymphatic drainage occurs. About one half of the lymphatic drainage of the left lung occurs via the right lung, this, along with the greater size of the right lung compared to the left, may account for the higher incidence of pulmonary oedema that occurs following right pneumonectomy. Other contributing factors may be:

i. decreased pulmonary capillary oncotic pressures due to the effects of excessive fluid administration
ii. endothelial damage due to excessive ventilating pressures

Re-expansion pulmonary oedema may occur in the operative lung following lobectomy or following drainage of a large pleural effusion.

For the above reasons, it is important to avoid fluid overload in patient undergoing lung resection:- eg.no more than 10ml/kg of crystalloid in the first hour intraoperatively and 1.5L in the first 24 hours postoperatively. Blood transfusion should be commenced at the usual clinical triggers. If colloids have been administered, they may worsen the severity of subsequent pulmonary oedema as they cannot be resorbed as quickly as crystalloid and hence should be avoided

Intercostal Drains

Following lobectomy, 1 or 2 pleural drains are connected to an underwater seal drain. The drainage bottles must be at least 1metre below the patient's chest to prevent aspiration of fluid back into the pleural cavity. The drainage tubes must be clamped if the drainage bottles are elevated for any reason. The underwater seal drain should either be on suction or open to air.

Following pneumonectomy, a single drain is placed which should be clamped and intermittently unclamped, this drain must not be on suction as cardiac herniation may occur.

Hourly blood drainage should be recorded from all chest drains.

Postoperative Analgesia

Thoracotomy is among the most painful of all operative procedures. Good analgesia is essential not only for obvious compassionate reasons, but also because hypoventilation due to pain may increase the risk of postoperative pulmonary complications(7).

i. *Systemic opioids:* Systemic opioids remain the mainstay of post-thoracotomy analgesic techniques. Their major clinical limitation is a narrow therapeutic window. It is important to appreciate that the inter-individual variability in opioid requirement following thoracotomy varies by a factor of up to ten. Hence Patient Controlled Analgesia (PCA) is the preferred technique, after adequate loading has occurred. However, a well-controlled opiate infusion may provide comparable analgesia.
ii. *NSAIDS:* NSAIDs have opioid-sparing benefits when commenced postoperatively. They do not produce respiratory depression and with short-term use, complications such as gastrointestinal bleeding and renal dysfunction are rarely a problem.
iii. *Epidural analgesia:* A wide variety of epidural techniques have been trialed, including lumbar versus thoracic, local anaesthetic alone versus opiates alone and in various combinations. (8-12). Thoracic epidural infusions of opiates appear to be more effective than lumbar, especially for relatively non-lipophilic opiates such as

pethidine. (8) Highly lipophilic opiates may cause acute respiratory due to systemic absorption, several studies have demonstrated that epidural administration of fentanyl may be equivalent to the intravenous route. Hydrophilic opiates such as morphine have the potential to produce delayed respiratory depression due to rostral spread to the brainstem. Thoracic local anaesthetic infusions are ineffective as sole agents and are associated with an unacceptably high incidence of hypotension and excessive motor block. Thoracic epidural combinations of dilute local anaesthetic and opiates have recently become popular, although some studies show no benefit from the addition of local anaesthetic compared with opiates alone.

iv. *Intercostal nerve blocks:* Intercostal nerve blocks performed intraoperatively are of benefit for a short period immediately postoperatively. Sustained benefit can be obtained by the use of local anaesthetic infusion into intercostal catheters placed under direct vision above and below the incision prior to wound closure.

v. *Interpleuaral analgesia:* Interpleural analgesia is performed by directly infusing local anaesthetic into the pleural cavity. It is of limited value following thoracotomy in adults. Analgesia is unreliable and loss of local anaesthetic occurs through the chest drain.

vi. *Cryoanalgesia:* Cryoanalgesia of intercostal nerves performed prior to wound closure produces intercostal blockade lasting several months. Despite the theoretical attractions, in one of the few controlled trials of the technique it did not produce improved pain scores or respiratory function. In addition, cryoanalgesia may lead to the development of intercostal neuralgia. (6)

SPECIFIC PROCEDURES

Bronchoscopy

Fiberoptic bronchoscopy may be performed awake or under general anaesthesia.

Rigid bronchoscopy requires a general anaesthetic with muscle relaxation to avoid trauma from coughing. A variety of ventilation techniques are available. Apnoeic oxygenation may be performed, oxygen is insufflated following a period of preoxygenation and hyperventilation. A ventilating side arm in the bronchoscope can be used to deliver high pressure oxygen and anaesthetic gases. High gas flows are needed due to gas leakage around the bronchoscope and hypoventilation frequently occurs. Care needs to be taken to avoid barotrauma. A Sanders injector can be used to deliver oxygen by jet ventilation in conjunction with an intravenous anaesthetic technique. A chest X-ray should be performed postoperatively to rule out pneumothorax or mediastinal emphysema from barotrauma.

Mediastinoscopy

The patient is usually head down with the head turned to the left so the scope can be advanced through the sternal notch anterior to the trachea. IPPV is preferred to spontaneous ventilation as there is less risk of venous air embolus. Other complications include pneumothorax, recurrent laryngeal nerve injury, haemorrhage, haemothorax and compression of the right innominate artery leading to a decrease in the right radial pulse.

Thoracoscopy

Thoracoscopy may be diagnostic or therapeutic. Diagnostic thoracoscopy may be performed under local or regional anaesthesia, but is usually performed under general anaesthesia with a double-lumen tube.

Thoracoscopic pleurodesis for recurrent pneumothorax is associated with severe postoperative pain and patients should receive either PCA opioids or an opioid infusion.

Patients undergoing thoracoscopic lung volume reduction surgery for severe emphysema may theoretically benefit from thoracic epidural analgesia as it may produce better respiratory function and less postoperative sedation than morphine PCA. An arterial line should be placed for perioperative blood gas analysis.Ventilating pressures are minimised to prevent air leak.

Mediastinal Mass

Anterior mediastinal masses may compress the superior vena cava (leading to SVC syndrome) the trachea and the heart. The extent to which these structures are involved must be established preoperatively. Supine dyspnoea is a particularly worrying symptom. CAT scans will delineate the anatomical extent of the mass, functional assessment can be obtained with spirometry performed in the upright and supine positions. A marked reduction in the supine FEV1 and PEFR indicates significant airway obstruction. Consideration should be given to preoperative radiotherapy.

If biopsy cannot be performed under local anaesthesia, a spontaneously ventilating anaesthetic is recommended to help maintain airway patency. This may be commenced following an awake fiberoptic intubation or by an inhalational induction, with the patient’s upper body elevated if the supine position is not tolerated. A rigid bronchoscope and a small diameter endotracheal tube should be immediately available to attempt to bypass a subglottic obstruction should loss of airway occur during induction. Another ventilating option is high frequency jet ventilation. Femoro-femoral cardiopulmonary bypass should be considered as a last resort.

If SVC obstruction is present, this will be aggravated by IPPV and the Trendelenberg position.

Pulmonary Haemorrhage

Immediate attempts should be made to protect the uninvolved lung. Double-lumen intubation is ideal, an alternative is to advance a single-lumen tube into the unaffected bronchus. Advencing the tube blindly will usually result in intubation of the right main bronchus (and occlusion of the right upper lobe bronchus). Left main bronchial intubation may be facilitated by using a fiberoptic bronchoscope as a guide, however, this may be difficult due to blood obscuring the view.

Bronchopleural fistula

Bronchopleural fistula may occur following lung resection (especially pneumonectomy), from rupture of a bulla or cyst, or due to carcinoma or trauma. There may be an associated empyema.

The anaesthetic goals are to achieve separation of the lungs in order to control ventilation in the presence of an air leak and to prevent cross contamination of the lungs.

If there is a chest tube in the affected side, it should be left unclamped prior to intubation. If there is no chest drain present, there is a risk of tension pneumothorax developing if IPPV is commenced before the lungs are separated. Hence intubation either awake or after an inhalational induction with spontaneous ventilation should be considered.

If the bronchopleural fistula is proximal, the endobronchial lumen should be inserted into the uninvolved side. Fiberoptic bronchoscopy is recommended to ensure accurate tube positioning.

High frequency ventilation may be ineffective and even worsen the bronchopleural fistula.

Bronchial lavage

Warm normal saline may be infused directly into the bronchial lumen of a double lumen tube to wash out secretions in conditions such as alveolar proteinosis, bronchiectasis, severe asthma, cystic fibrosis or following inhalation of radioactive dust. It is important that the lungs are accurately separated to prevent fluid and secretions contaminating the untreated lung, the bronchial cuff should not leak at less than 50cmH2O inflating pressure. Following instillation of saline, physiotherapy is performed on the chest and then passive drainage of the lung is performed with the patient head down. Multiple lavages may be necessary involving many changes in patient position, hence there is a risk of displacement of the endobronchial tube. Hypoxia commonly occurs- if it is due to cross-contamination of the lungs, two-lung ventilation with PEEP should be commenced.

Lung cysts and bullae

Apical blebs tend to occur in young patients, while emphysematous blebs are found in older patients with advanced chronic airways disease.

Large bullae may rupture due to positive pressure ventilation. Prior to one lung ventilation, excessive ventilating pressures should be avoided along with nitrous oxide. Resection of isolated bullae is usually performed thoracoscopically, more extensive disease may require thoracotomy.

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