# 10

# Anaesthesia for thoracic surgery

## Anaesthetic techniques

Anaesthetic techniques for thoracic surgery (Table 10.1) are little different from those used in other forms of major surgery. Anaesthesia is induced intravenously and endobronchial intubation is performed following the administration of a non-depolarizing neuromuscular blocking drug. The depolarizing agent suxamethonium is indicated, however, if a difficult laryngeal intubation is likely, or if another airway problem, such as a bronchopleural fistula, is present.

Maintenance of anaesthesia is usually with an inhalational agent such as isoflurane, combined with an intravenous opioid, but it is equally acceptable to use a total intravenous technique.

If epidural opioids are to be used to provide postoperative pain relief, then it is preferable to avoid the use of intravenous opioids during surgery. Postoperative analgesia is discussed in Chapter 12.

The choice between inhalational anaesthesia and intravenous techniques during one-lung ventilation is controversial. In practice, there is little difference in the oxygenation achieved with each technique.

## Monitoring

Monitoring and vascular access for major thoracic surgery should be comprehensive, (Table 10.2). A pulmonary artery catheter is unnecessary in routine practice.

## Isolation of the lungs

Separation of the lungs to facilitate one-lung ventilation (OLV) and prevent spread of secretions, pus and blood from one lung to other is usually achieved with a double-lumen endobronchial tube (DLT). The advent of video-assisted thoracoscopic surgery (VATS) has increased the use of endobronchial intubation because it is mandatory to collapse the lung on the side of thoracoscopic surgery to allow safe access via telescope and instrumentation ports. There has also been a resurgence of interest in the use of bronchial blockade, particularly with the Univent tube.

**Table 10.1 Anaesthetic techniques suitable for major thoracic surgery**

**Induction**
Propofol
- Satisfactory in most patients; repeat, as necessary, to prevent awareness during preoperative bronchoscopy.
- Target-controlled infusion useful for longer procedures and prolonged bronchoscopy

Etomidate
- Elderly or those with cardiovascular instability

**Neuromuscular blockade**
Choice of non-depolarizing agent not critical
Consider suxamethonium for difficult intubation, or airway fistula

**Maintenance of anaesthesia**
Inhalational agent
- Isoflurance most suitable
- Avoid halothane: has marked inhibitory effect on hypoxic pulmonary vasoconstriction

Inspired gas mixture: 50% oxygen in nitrous oxide or air
- Avoid nitrous oxide with abnormal air spaces
- Increase inspired oxygen concentration for one-lung ventilation (air/oxygen combination preferable)

Total intravenous anaesthesia
- Propofol by target controlled infusion: combine with remifentanil infusion?

Intraoperative analgesia
- Morphine (0.1–0.2 mg/kg) based on age/physical status, etc., supplement at end of surgery
- Fentanyl (5–15 μg/kg): alternative
- Avoid intravenous opioids if epidural opioids used

Epidural analgesia
- Thoracic/high lumbar/lumbar: all feasible
- Opioids alone or combined with low-dose local anaesthetic agents

**Table 10.2 Monitoring: major thoracic surgery**

- Electrocardiogram
- Pulse oximetry
- End-tidal gas analysis
  Oxygen
  Carbon dioxide (invaluable during one-lung ventilation)
  Inhalational agent
- Flow/volume loop
  Useful during one-lung ventilation
- Invasive arterial pressure measurement
  Arterial cannula in radial artery contralateral to side of surgery because of the position of the arm
- Central venous pressure measurement/volume line
  Multilumen catheter in the internal jugular on the side of surgery
- Nasopharyngeal temperature
  Heat loss significant during thoracotomy
- Urinary output measurement

## Endobronchial intubation

It is preferable to use a left-sided DLT whenever possible because this avoids the problem of the early 'take-off' of the right upper lobe bronchus. A left-sided DLT can be used for the majority of VATS procedures, but it is accepted UK practice to place a DLT in the lung contralateral to surgery to facilitate lung resection. Indications for endobronchial intubation theoretically range from absolute to relative (Table 10.3).

**Table 10.3 Indications for endobronchial intubation**

| | |
|---|---|
| **Absolute** | Fistula or ruptured airway |
| | Lung transplantation |
| | Video-assisted thoracoscopic surgery |
| | Intrapulmonary bleeding |
| | Profuse secretions |
| | Lung cysts |
| | Lung resection |
| | Thoracic aortic/spinal surgery |
| | Oesophageal surgery |
| **Relative** | Open pleurectomy |

In practice, one-lung ventilation is used to facilitate all the above procedures if satisfactory oxygenation can be maintained.

### *Double-lumen endobronchial tubes*

DLTs are derived from the Carlens tube which was introduced in 1949 to allow measurement of lung volumes separately in the two lungs (differential bronchospirometry).

The majority of tubes available are based on a design by the British anaesthetist Robertshaw and incorporate an endobronchial limb, a tracheal limb and both tracheal and bronchial cuffs. They are shaped to fit into the airway with a proximal oropharyngeal curve and a distal bronchial curve. The bronchial cuff design is different between the left and right tubes because the right upper lobe orifice occurs a shorter distance after the carina than the left upper lobe orifice (Fig. 10.1). Most right tubes have a ventilation slot (or similar arrangement) built into, or distal to, the right bronchial cuff for right upper lobe ventilation. Left tubes do not have this feature because of the longer left main bronchus. The basic pattern of a right DLT is shown in Fig 10.2. Endobronchial tubes are made to a similar pattern by numerous different manufacturers.

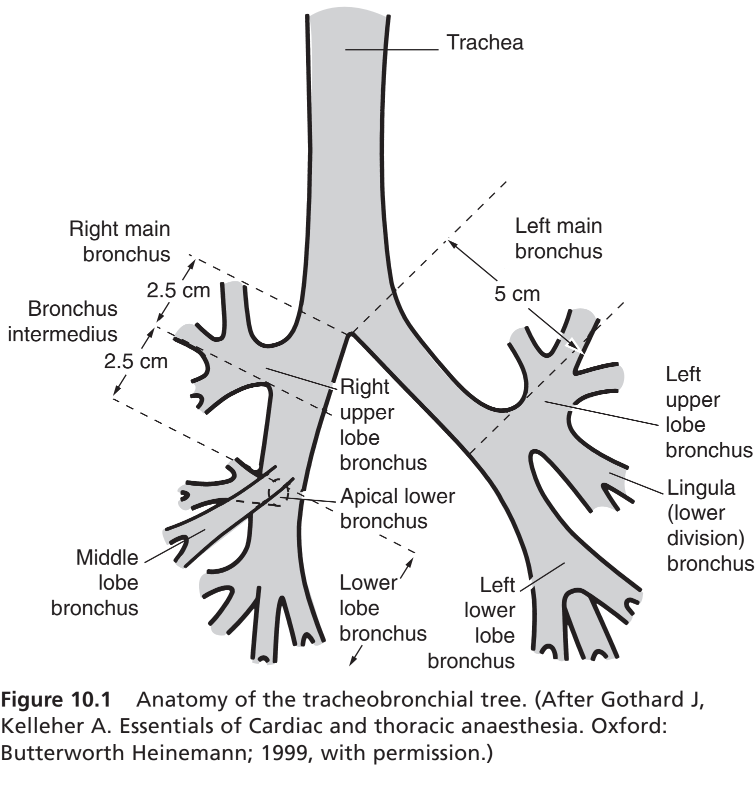


**Figure 10.1** Anatomy of the tracheobronchial tree. (After Gothard J, Kelleher A. Essentials of Cardiac and thoracic anaesthesia. Oxford: Butterworth Heinemann; 1999, with permission.)

Table 10.4 lists the features of two types of endobronchial tube (Robertshaw and Bronchocath) commonly used in the UK.

The size of tube to be used, and depth of insertion of certain tubes, is based to some extent on the age, weight, height and sex of the patient

**Table 10.4 Comparison of Robertshaw and Bronchocath endobronchial tubes**

| Robertshaw (Phoenix Medical Ltd) | Bronchocath (Mallinckrodt) |
|---|---|
| **Construction** | **Construction** |
| Disposable (coated rubber) also red rubber reusable<br>Bronchial limb and cuff colour-coded blue | Polyvinylchloride<br>Disposable<br>Low-pressure/high volume cuffs<br>Colour-coded blue bronchial cuff and bronchial limb<br>Radio-opaque markings |
| **Sizes** | **Sizes** |
| Right and left<br>Large, medium, small, extra-small | Right and left<br>35, 37, 39 and 41-French gauge<br>Left 28-French gauge |
| **Features** | **Features** |
| 'Bite-block' where tracheal and bronchial limbs fuse is designed to sit at level of teeth; in practice this may be too deep<br>Slot in bronchial cuff (21 mm – large tube) almost twice the length of equivalent Bronchocath, therefore more likely to be opposite the right upper lobe orifice | Depth of insertion variable<br>Length markers on side of tube<br>Right upper lobe ventilation slot only 11 mm in 41-French gauge tube<br>Easier to use with fibreoptic bronchoscope. Standard anaesthetic fibreoptic bronchoscope will pass down 35-French gauge tube |
| **Clinical use** | **Clinical use** |
| Relatively bulky tubes, easy to insert and less likely to move intraoperatively than plastic tubes<br>Less easy to manipulate with a fibreoptic bronchoscope. The small and extra-small sizes will only allow passage of a paediatric fibreoptic bronchoscope | Not as stable after insertion as Robertshaw tube<br>Greater size range useful, especially in small women/adolescents<br>Malleable plastic tubes useful for 'rail-roading' techniques with a fibreoptic bronchoscope and difficult laryngeal intubation |

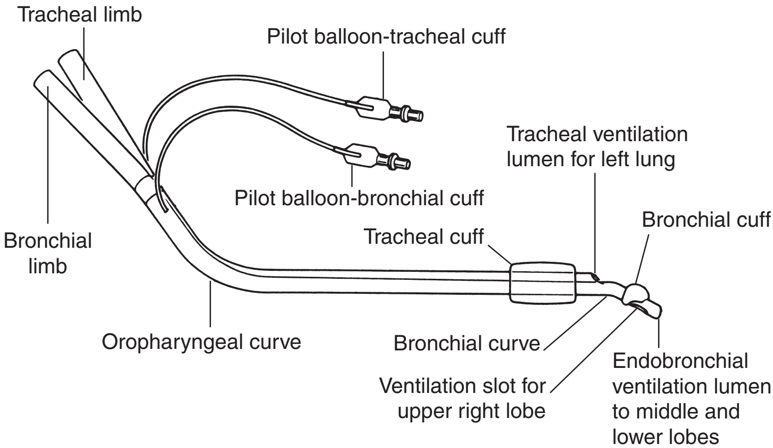


**Figure 10.2** Basic pattern of a right-sided double-lumen endobronchial tube. (After Gothard J. Anaesthesia for thoracic surgery, 2nd edn. Oxford: Blackwell Scientific Publications; 1993, with permission.)

(Table 10.5). Once the initial choice of tube is in place, its position is checked clinically and by fibreoptic bronchoscopy (FOB) and this may indicate that a different size of tube is necessary.

### *Placement of double-lumen endobronchial tubes*

DLTs are usually placed in the lung contralateral to surgery but, as discussed above, left-sided tubes are placed where possible for

**Table 10.5 Recommendations for size and length of left double-lumen tube. (Adapted from Brodsky et al. 1991, 1996.)**

**Length of tube**

Male/females 170 cm tall: insert tube to a depth of 29 cm
For every 10 cm increase in height, increase depth of insertion by 1 cm

**Size of tube from measured tracheal width**

| Width of trachea (mm) | Tube size (French gauge) |
|---|---|
| 18 | 41 |
| 16 | 39 |
| 15 | 37 |
| 14 | 35 |

The above lengths and sizes are not necessarily applicable to right-sided tubes.

other types of surgery to overcome the problem of right upper lobe ventilation.

DLTs are introduced into the larynx in the usual way, sometimes aided with a bougie. The tube is then advanced 'blindly' (after removing any stilette provided) with a twisting motion towards the side of insertion. The curved endobronchial portion of the tube is usually deflected at the carina and passes into the appropriate main bronchus.

Once in place, the tracheal cuff is inflated whilst both lungs are ventilated and the seal checked in the usual way. The tracheal limb of the DLT is then opened to air and the double-lumen catheter mount clamped so that only the bronchial limb is ventilated. The bronchial cuff is then inflated with a minimum amount of air to seal the cuff and eliminate any leak of gas from the intubated lung up through the open tracheal limb. This step is important for two reasons. First, a good seal is required to establish satisfactory one-lung anaesthesia during surgery and, second, bronchial rupture has been reported after overinflation of the bronchial cuff.

During this process, the position of the tube is checked by observing chest movements with inflation/deflation and by alternate auscultation of both lung fields, paying particular attention to the left upper lobe with a left-sided tube and the right upper lobe with a right-sided tube. Auscultation is also carried out first with the tracheal limb, and then the endobronchial limb, occluded at the catheter mount to ascertain that isolation of the lungs has been achieved. Finally, the change in airway pressure is noted when OLV is started. These checks are repeated after the patient has been turned into the lateral position for thoracotomy, because it is not uncommon for the tube to move at this time.

There is increasing evidence that clinical checks of tube position are inaccurate and that it is preferable to check the position of endobronchial tubes with an FOB.

### *Fibreoptic bronchoscopy and double-lumen tube placement*

The introduction of slim, relatively inexpensive, FOB/laryngoscopes has made the routine inspection of endobronchial tubes a practical possibility.

The FOB can be used to place the endobronchial tube under direct vision in patients who are difficult to intubate, or when the tube cannot be located blindly in the appropriate bronchus. In the latter situation, it is a relatively simple task to insert a DLT into the trachea, locate the appropriate main bronchus with an FOB passed down the tube and then 'railroad' or slide the tube into position over the bronchoscope

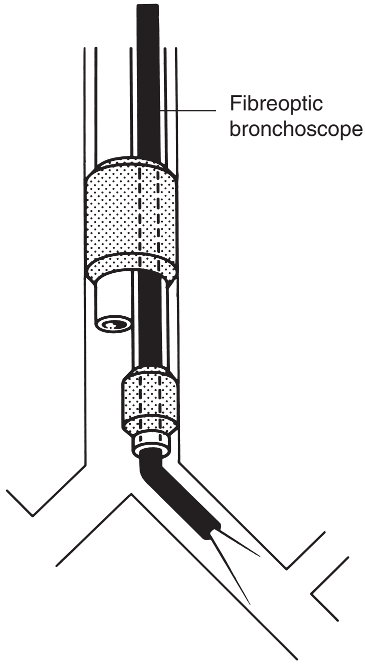


**Figure 10.3** Positioning of a double-lumen tube with the fibre-optic bronchoscope. (After Aitkenhead AR, Jones RM. Clinical Anaesthesia. Edinburgh: Churchill Livingstone; 1996, with permission.)

(Fig. 10.3). The flexibility of plastic tubes is a distinct advantage when the FOB is used in this way.

In the majority of cases, the FOB will be used to check the position of tubes following blind placement. The sequence for checking the position of a DLT is described below.

The FOB (Fig 10.4) is first passed down the tracheal lumen of the DLT to check that there is a clear view of the main bronchus of the lung to be operated upon and that the bronchial cuff is not herniating over the carina. (The bronchial cuff of the majority of tubes is coloured blue for easy endoscopic identification.) The FOB is then passed down the endobronchial limb to ensure that the upper lobe orifice is not obstructed on the left and that the ventilation slot of a right tube is apposed to the upper lobe orifice (Fig 10.5). If manipulation of the tube is necessary, the tracheal lumen should be rechecked. It is also advisable to repeat the procedure after the

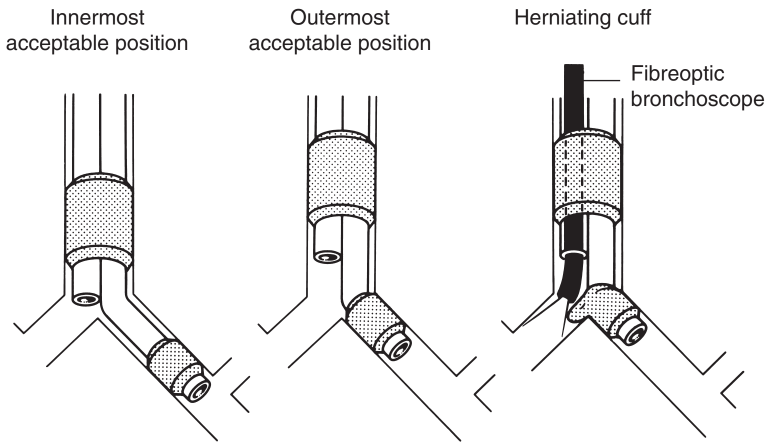


**Figure 10.4** Left-sided double-lumen tube position. (After Aitkenhead AR, Jones RM. Clinical Anaesthesia. Edinburgh: Churchill Livingstone; 1996, with permission.)

patient has been positioned for surgery. Despite accurate initial placement of endobronchial tubes, movement can occur during surgery, and repositioning can be difficult. It is useful to note the length of the tube at the teeth when it is first placed because this can be used later to estimate whether the tube has slipped in or out of the main bronchus.

## Bronchial blockade

Bronchial blockers have been used intraoperatively for many years to block off individual lobes and facilitate OLV. There has been renewed interest in using bronchial blockade which has led to the development of a combined endotracheal tube and bronchial blocker, the Univent tube, and the availability of single endobronchial blockers.

### *The Univent tube*

The Univent tube comprises an endotracheal tube with a moveable bronchial blocker attached (Fig 10.6).

The tracheal tube has a small channel through the anterior internal wall which holds a bronchial blocker with a low pressure, high-volume cuff. The tube is placed in the trachea in the usual way and the blocker advanced, preferably under FOB control, to block the appropriate main or lobar bronchus. The blocker is then locked in place (Table 10.6).

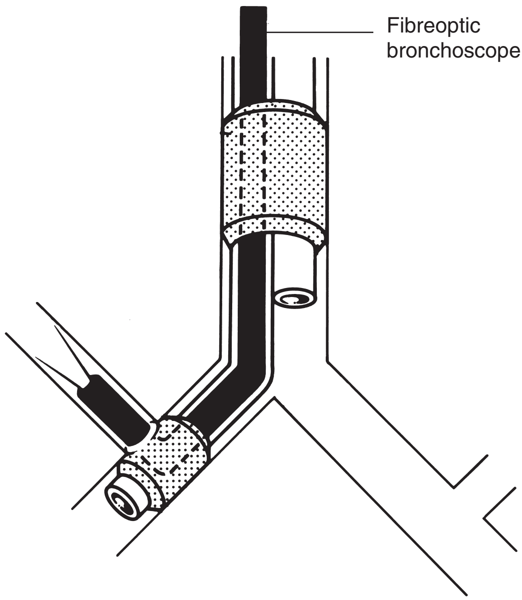


**Figure 10.5** Right-sided double-lumen tube in position. (After Aitkenhead AR, Jones RM. Clinical Anaesthesia. Edinburgh: Churchill Livingstone; 1996, with permission.)

**Table 10.6 Univent tube**

| Advantages | Disadvantages |
|---|---|
| Lobar blockade possible | Less versatile than double-lumen tube, problem with pneumonectomy |
| Ease of use for difficult intubation | Inflation/deflation of the lung more difficult |
| Facilitates aspiration of secretions | Blocker can migrate |
| No tube exchange if ventilation continued postoperatively | More expensive than double-lumen tube |

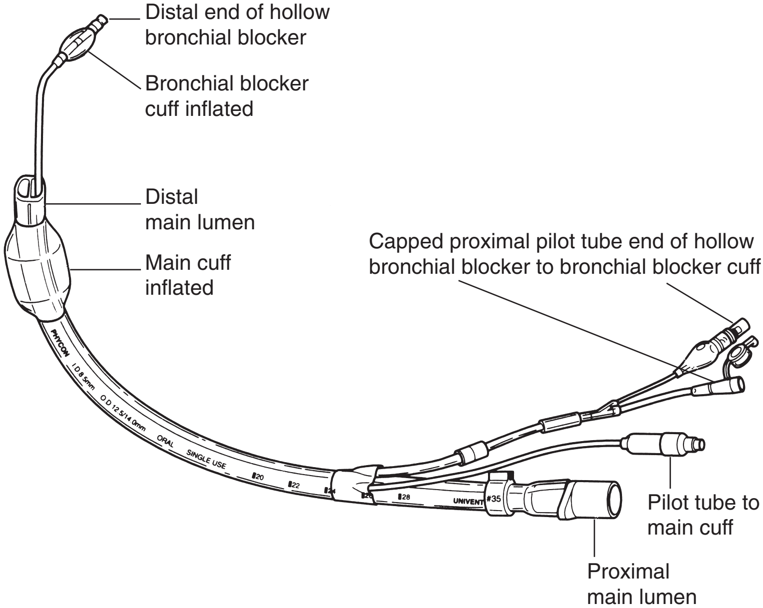


**Figure 10.6** Univent tube-combined endotracheal tube and bronchial blocker. (After Gothard J, Kelleher A. Essentials of cardiac and thoracic anaesthesia. Oxford: Butterworth Heinemann; 1999, with permission.)

## Ventilation during thoracotomy

### *Physiological consequences of the lateral thoracotomy position*

In the awake subject, there is little or no additional ventilation/perfusion mismatch in the lateral position. The situation changes during anaesthesia. In the spontaneously breathing subject, there is a reduction in inspiratory muscle tone (particularly the diaphragm) and a decrease in the volume of both lungs with a reduction in functional residual capacity. The compliance of the non-dependent upper lung increases and it receives more ventilation. Paralysis and intermittent positive pressure ventilation are used during thoracotomy and the compliance of the non-dependent lung is increased even further. In practice, it is usual to selectively ventilate the lower lung (OLV) at this point and allow the upper lung to collapse. This eliminates the preferential ventilation and facilitates surgical access, but creates the more serious problem of ventilation/perfusion mismatch.

## *Physiology of one-lung anaesthesia*

### *Venous admixture*

Pulmonary blood flow continues to the upper lung during one-lung anaesthesia, creating a true shunt in a lung where there is blood flow to the alveoli but no ventilation. This shunt is the major cause of hypoxaemia during OLV, although the alveoli with low ventilation/perfusion ratios in the dependent lung also contribute. In addition, the blood to the upper lung cannot take up oxygen and therefore retains its poorly oxygenated mixed venous composition. This mixes with oxygenated blood in the left atrium causing venous admixture and lowering arterial oxygen tension ($PaO_2$). Total venous admixture can be calculated from the shunt equation which estimates what proportion of the pulmonary blood flow would have bypassed ventilated alveoli to produce the arterial blood gas values for a particular patient. Venous admixture and shunt (Qs/Qt) are often used synonymously.

Venous admixture increases from a value of approximately 10% to 15% during two-lung ventilation to 30% to 40% during OLV. The $PaO_2$ can be maintained in the range of 9–16 kPa with an inspired oxygen concentration between 50% and 100% in the majority of patients.

### *Hypoxic pulmonary vasoconstriction and one-lung ventilation*

Hypoxic pulmonary vasocontriction (HPV) is a mechanism whereby pulmonary blood flow is diverted away from hypoxic/collapsed areas of lung. This should improve oxygenation during OLV. Volatile anaesthetic agents depress HPV directly, but also enhance HPV by reducing cardiac output. There is therefore no change in the HPV response with volatile agents during thoracotomy and OLV.

Intravenous agents, such as propofol, do not inhibit HPV and should improve arterial oxygenation during OLV. There is some evidence to support this contention.

### *Cardiac output*

Changes in cardiac output affect arterial oxygenation during thoracotomy. A decrease in cardiac output results in a reduced mixed venous oxygen content. Some of this desaturated blood is shunted during OLV and further exacerbates arterial hypoxaemia. Cardiac output can decrease for a number of reasons during thoracotomy. These include blood loss/fluid depletion, the use of high inflation pressures and the application of positive end-expiratory pressure (PEEP) to the dependent lung.

Surgical manipulation and retraction around the mediastinum, causing a reduction in venous return, are probably the commonest causes of a sudden drop in cardiac output during lung resection.

*Principles of ventilation (Table 10.7)*

OLV should be established to adequately inflate the lung but also minimize intra-alveolar pressure and so prevent diversion of pulmonary blood flow to the upper lung. In practice, this is not easy to achieve. It is reasonable to use an inspired oxygen concentration of 50% initially, which can be increased to 100%, if required. This cannot affect the true shunt in the upper lung but improves oxygenation through the alveoll with low V/Q ratios in the lower lung.

Overinflating the single lung ('volutrauma') can be detrimental and lead to acute lung injury. Deflation and inflation of the operative lung with the potential for ischaemia/reperfusion injury has also been implicated in lung damage. The use of low tidal volumes improves outcome in ventilated patients with adult respiratory distress syndrome and this may also apply to OLV. Limiting ventilation can lead to carbon dioxide retention, but a degree of permissive hypercapnia is preferable to lung trauma.

*Hypoxia during one-lung ventilation*

It is difficult to predict which patients are likely to be hypoxic ($SpO_2$ < 90%) during OLV. Patients with poor lung function are sometimes accepted for lung resection on the basis that their diseased lung is contributing little to gas exchange and this can be confirmed by V/Q scanning. Conversely, patients with normal lung function are more likely to be hypoxic during OLV because an essentially normal lung is collapsed to

**Table 10.7 Guidelines for managing one-lung ventilation**

| |
|---|
| Inspired oxygen concentration of 50% to 100% |
| Increase if $SpO_2$ < 90% |
| Normal inspired/expired ratio (1 : 2) |
| Increase expiratory phase if gas trapping likely |
| Consider pressure limiting ventilation |
| Use small tidal volumes (e.g. 6–7 ml/kg) |
| Allow permissive hypercapnia |
| Use positive end-expiratory pressure in hypoxic patients |
| Avoid overinflation ('volutrauma') |

provide surgical access. The most significant predictors of a low arterial oxygen saturation during OLV are (1) a right-sided operation, (2) a low oxygen saturation during two-lung ventilation prior to OLV and (3) a high (or more normal) forced expiratory volume in 1 s preoperatively.

Once hypoxia occurs, it is important to check the position of the endobronchial tube and readjust this if necessary. A high inflation pressure (> 30–35 $cmH_2O$) may indicate that the tube is displaced. It may be helpful to analyse a flow/volume loop or at least manually reinflate the lung to feel the compliance. If a tube is obstructing a lobar orifice, only one or two lobes are being ventilated at most and hypoxia is likely. Suction and manual reinflation of the dependent lung may be useful.

Other measures which can be used to improve oxygenation include increasing the inspired oxygen concentration, introducing PEEP to the dependent lung, or supplying oxygen to the upper lung by via a continuous positive airway system, thereby reducing the shunt.

In the face of persistent arterial hypoxaemia during OLV, it is pertinent to ask 'What is a low $PaO_2$ for this patient?'. An oxygen saturation below 90% is commonly used. This arbitrary figure is affected by a variety of factors, including acidosis and temperature. Many patients will have a low $PaO_2$ when measured breathing air preoperatively; hence, the usefulness of this preoperative measurement. Arterial hypoxaemia is obviously undesirable but it may be preferable to accept a $PaO_2$ slightly lower than the preoperative value, rather than undertake measures such as upper lung inflation which may hinder and prolong surgery.

### *High-frequency jet ventilation*

High-frequency jet ventilation (HFJV) can be used to provide satisfactory gas exchange during thoracotomy either by an endotracheal tube or some form of endobronchial tube. HFJV provides satisfactory ventilation by either route and has the advantage of low peak airway pressures, albeit with the production of obligatory PEEP by the majority of systems. Some clinicians advocate the use of HFJV during thoracic surgery and use it routinely. This method of ventilation has not been adopted widely as a result of difficulties with surgical access because the lung is distended and gaseous anaesthetic agents cannot be administered.

### *New modalities and one-lung anaesthesia*

Ventilation, is the main area in which changes are made to reduce hypoxia during OLV. Increasing interest is shown in the pharmacological manipulation of pulmonary blood flow during OLV with prostaglandin $E_1$ and nitric oxide.

### *Termination of surgery and anaesthesia*

*Testing of bronchial suture lines*

On completion of lung resection, the bronchial suture lines and lung surfaces are tested for an air leak. Sterile water is instilled into the pleural cavity, following cancer surgery, to cover the bronchial suture lines. After lobectomy, the remaining lobe or lobes are then suctioned before reinflation. In the case of pneumonectomy, very gentle suction is applied with a soft catheter to the bronchial stump. At this stage, it may be helpful to deflate the bronchial cuff. The bronchial stump is then tested for a leak as a positive pressure of approximately 25 $cmH_2O$ is applied manually in a sustained manner to both lumina of the DLT.

In the unlikely event of a leak being present, gas bubbles will be seen appearing below the water level in the pleural cavity, indicating the need for further surgery. Testing for lung surface leaks is undertaken at a lower inflation pressure of approximately 20 $cmH_2O$.

### *Termination of anaesthesia*

After completion of lung resection and closure of the chest wall, anaesthesia is lightened and spontaneous ventilation re-established in the usual manner. Before removal of the endobronchial tube, the patient is placed in a supine position. Following lobectomy, tracheobronchial suction is carried out to clear secretions and blood in the bronchi of the intact lung and the remaining lobes of the operated lung. The lungs are then manually reinflated again, also at a low pressure, with the chest drains open to an underwater seal drain. The endobronchial tube is removed when the patient's respiratory effort is satisfactory.

A similar sequence is followed after pneumonectomy but the remaining lung is reinflated until the trachea is approximately central, or slightly towards the side of surgery. The chest drain, if inserted, is then clamped. If a chest drain has not been used after pneumonectomy, it may be necessary to aspirate air from the hemithorax on the side of surgery to optimize the position of the mediastinum.

Patients are placed in the sitting position after removal of the DLT and allowed to breathe oxygen-enriched air. Further postoperative care is supervised in a high-dependency or intensive care unit.

## Further reading

Aitkenhead AR, Jones RM (eds). Clinical anaesthesia. Edinburgh: Churchill Livingstone; 1996.

Brodsky JB, Benumof JL, Ehrenwerth J, Ozaki GT. Depth of placement of left double-lumen endobronchial tubes. Anesth Analg 1991;73:570–572.

Brodsky JB, Macario A, Mark BD. Tracheal diameter predicts double-lumen tube size: a method for selecting left double-lumen tubes. Anesth Analg 1996;82:861–864.

Chen TL, Lee YT, Wang MJ, Lee JM, Lee YC, Chu SH. Endothelin-1 concentrations and optimisation of arterial oxygenation by selective pulmonary artery infusion of prostaglandin $E_1$ during thoracotomy. Anaesthesia 1996;51:422–426.

Cohen E. Methods of lung separation. Curr Opin Anaesthesiol 2002;15:69–78.

Gosh S, Latimer RD. Thoracic anaesthesia: principles and practice. Oxford: Butterworth Heinemann; 1999.

Gothard JWW. Anaesthesia for thoracic surgery, 2nd edn. Oxford: Blackwell Scientific Publications; 1993.

Inoue H, Shotsu A, Ogawa J, Kawada S, Koide S. New device for one-lung anaesthesia: endotracheal tube with movable blocker. J Thorac Cardiovasc Surg 1982;83:940–941.

Kellow NH, Scott AD, White SA, Feneck RO. Comparison of the effects of propofol and isoflurane anaesthesia on right ventricular function and shunt fraction during thoracic surgery. Br J Anaesth 1995;75:578–582.

Nunn JF. Applied respiratory physiology, 4th edn. London: Butterworth Heinemann; 1993.

Reid CW, Slinger PD, Lenis S. A comparison of the effects of propofol-alfentanil anesthesia on arterial oxygenation during one-lung ventilation. J Cardiothorac Vasc Anesth 1996;10:860–863.

Robertshaw FL. Low resistance double-lumen endobronchial tubes. Br J Anaesth 1962;34:576–579.

Tugrul M, Camci E, Karadeniz H, Senturk M, Pembeci K, Akpir K. Comparison of volume controlled with pressure controlled ventilation during one-lung anaesthesia. Br J Anaesth 1997;79:306–310.

Williams EA, Evans TW, Goldstraw P. Acute lung injury following lung resection: is one lung anaesthesia to blame? Thorax 1996;51:114–116.

Wilson WC, Kapelanski DP, Benumof JL, Johson FW, Channick RN. Inhaled nitric oxide (40 ppm) during one-lung ventilation, in the lateral decubitus position does not decrease pulmonary vascular resistance or improve oxygenation in normal patients. J Cardiothorac Vasc Anesth 1997;11:172–176.