Anaesthesia for telescopic procedures in the thorax

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Over the past decade, there has been an increase in endoscopic procedures within the thorax for diagnosti
c and therapeutic purposes. Each has its indica
tions, techniques and complications. However, the
one common denominator is that there is always the
possibility that thoracotomy may be necessary. Occa
sionally, particularly if considerable haemorrhage
occurs, thoracotomy may be required immediately.
Consequently, the clinical examination and investi
gations should be orientated to this possibility. The
medical and theatre staff should be prepared for, and
trained to deal with, such an eventuality.

GENERAL PREOPERATIVE CONSIDERATIONS

Patients should undergo a complete evaluation for a
full posterolateral thoracotomy. The goal is to define
all of the problems and to ascertain if the patient is in
the best possible condition. Factors known to
increase the risk for patients undergoing thoracic
surgery include cigarette smoking, advanced age,
coronary artery disease, preoperative weight loss,
obesity, poor pulmonary function and duration of
surgery.22

Cardiac risk is determined by the severity of coro
nary artery disease, presence of cardiac arrhythmias,
left ventricular dysfunction, age and associated
medical conditions such as hypoxaemia, diabetes and
renal insufficiency.28 An exercise stress test should be
performed as patients with ischaemia are at a higher
risk of perioperative cardiac complications and death
when undergoing major operations such as pneu
monec tomy.22 Consideration should be given to
cardiac catheterization and, if appropriate, coronary
artery bypass grafting before major lung resection.
However, it is not known if this is true for patients
undergoing thoracoscopic pulmonary resection.

The preoperative evaluation of the respiratory sys
tem involves taking a history, physical examination,
exercise tolerance, routine laboratory tests, including
arterial blood-gas tensions, radiography and pulmo
nary function tests. Patients who show an increase in
peak expiratory flow rate by 15% or more after
administration of bronchodilators should receive
perioperative bronchodilators. A forced vital capacity
(FVC) of at least three times the tidal volume is nec
essary for an effective cough and a value of less than
50% of predicted is an indicator of increased risk of
postoperative ventilator dependency.31 A maximum
voluntary ventilation less than 50% of predicted is
another poor prognostic indicator and indicates pos
sible postoperative atelectasis and infection.22 In
patients with marginal pulmonary function who are
considered for lung resection, a quantitative
ventilation–perfusion scan is indicated. The percent
of perfusion delivered to the lung which is to be
resected is multiplied by the preoperative FVC or
forced vital capacity in 1 s (FEV₁). Patients who have
a predicted postoperative FEV₁ of less than 800 ml
are generally considered a prohibitive operative risk.
At least 2 u. of blood should normally be available.
However, grouping and saving of serum should be
sufficient cover for bronchoscopy.

Bronchoscopy

Bronchoscopy is the oldest and most frequently per
formed endoscopic procedure used in the assess
ment and management of patients with pathology in
the thoracic cavity. It may be rigid or flexible. The first
rigid bronchoscopy was performed by Gustav Hillian
in 1897. The technique was developed by Chevalier
Jackson in the USA and by Victor Negus in the UK
in the early years of the 20th century. The flexible
fiberoptic bronchoscope was introduced into clinical
practice by Shigeto Ikeda in 1968.

The roles of rigid and flexible fiberoptic bronchosco
py in current clinical practice have been reviewed.25
Although rigid bronchoscopy has generally been
superseded by flexible fiberoptic bronchoscopy for
the initial assessment of airway and thoracic disease,
it remains the procedure of choice for surgical assess
ment before staging procedures such as mediastinosco
py and before thoracotomy. The rigid broncho
scope is also the preferred instrument for use in small
children, in adults with massive haemoptysis and for
therapeutic procedures such as foreign body re
moval, stent insertion and endoscopic resection of
airway tumours.

PREOPERATIVE ASSESSMENT

A full history and clinical examination are essential.
Patients who require bronchoscopy are frequently
cigarette smokers with hyper-reactive airway reflexes
and are likely to have impaired cardiovascular and

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gery, thoracoscopy

respiratory function. Preoperative assessment should be directed to the identification of such patients and to optimal control of co-existing medical conditions.

Preoperative investigations should include routine haematology and biochemistry, a 12-lead electrocardiograph in adults and a chest radiograph in all patients. More advanced imaging of the chest, such as computerized tomography or magnetic resonance scanning, in addition to pulmonary function tests and arterial blood-gas analysis may also be appropriate. If bronchoscopy is to be performed immediately before thoracotomy, such investigations are mandatory.

The chest radiograph is particularly important as it demonstrates areas of pulmonary collapse and consolidation, and highlights the presence of an air-filled cavity such as a lung bulla or a pneumothorax. In a patient who has inhaled a foreign body, chest radiographs performed at the end of inspiration and expiration may reveal an emphysematous area distal to the site of the foreign body. This indicates that the foreign body is acting as a “ball valve” in the lower airway, allowing air entry during inspiration but preventing the exit of the same volume of air during expiration. This radiographic finding contraindicates the use of nitrous oxide and positive pressure ventilation during general anaesthesia as a consequence of their potential to increase the size of an air-filled cavity, which may result in both respiratory and cardiovascular embarrassment. This is particularly important in children.

PREMEDICATION

Premedication should include the patient’s regular cardiovascular and respiratory medications. Diabetic patients should omit their usual oral antidiabetic medication. Those who are insulin-dependent should be managed using an i.v. glucose–insulin regimen. Particular attention should be paid to the preoperative control of bronchospasm as perioperative morbidity and mortality are particularly high in such patients.

A short-acting benzodiazepine may be administered to relieve preoperative anxiety without delaying recovery of consciousness at the end of the procedure. Sedative agents should, however, be avoided in the presence of upper airway obstruction. An anticholinergic agent may be administered to counter the muscarinic effects of the anaesthetic drugs to be used and the surgical procedure.

MONITORING

Minimum monitoring is essential for both flexible fiberoptic and rigid bronchoscopy, whether the procedure is to be performed with sedation and local anaesthesia or with general anaesthesia, as cardiovascular and respiratory complications are common. Minimum monitoring should comprise an electrocardiograph, an intermittent non-invasive method to measure arterial pressure and continuous pulse oximetry to measure arterial oxygen saturation. Capnography should also be used during flexible fiberoptic bronchoscopy under general anaesthesia, but is not easily adapted for use with the unsealed airway during rigid bronchoscopy. Monitoring should always be attached before administration of sedative or anaesthetic agents and continued until the patient has recovered fully from the procedure. In future, the use of transcutaneous carbon dioxide monitoring may be an appropriate alternative, particularly in children and during prolonged procedures.

FLEXIBLE FIBROOPTIC BRONCHOSCOPY

The flexible fiberoptic bronchoscope is available in varying sizes for use both in children and adults. Passage of the bronchoscope via the nose or mouth is a relativelyatraumatic procedure and can be performed under sedation and topical anaesthesia in the majority of patients. General anaesthesia is reserved for children and those adults who are unable to tolerate the procedure awake.

Sedation is usually provided by a combination of a benzodiazepine and an opioid. Propofol by continuous infusion may also be used safely as a sedative for flexible fiberoptic bronchoscopy. If passage of the bronchoscope via the nose is required, the nasal mucosa can be anaesthetized using either cocaine or one of the newer local anaesthetic agents in combination with a vasoconstrictor. A detailed description of the methods available to produce topical anaesthesia of the lower respiratory tract is beyond the scope of this review. In practice, local anaesthetic agents may be effectively administered by nebulization, cricothyroid puncture or using a “spray as you go” technique. Large doses of local anaesthetic agents are required for effective topical anaesthesia. Systemic absorption resulting in local anaesthetic toxicity is a significant risk.

In the anaesthetized patient, the flexible fiberoptic bronchoscope is usually introduced into the trachea via a self-sealing diaphragm in the angle piece attached to a tracheal tube. Ventilation of the lungs with an anaesthetic gas mixture of known concentration can be continued around the outside of the bronchoscope but within the lumen of the tracheal tube. The presence of the bronchoscope within the tracheal tube reduces the available internal cross-sectional area and increases resistance to the flow of gas via the tracheal tube. Consequently, it is important to use the largest feasible tracheal tube in each individual patient. It is also usual to administer neuromuscular blocking agents and to control ventilation, a technique which has been shown to maintain satisfactory gas exchange.

The laryngeal mask airway (LMA) has also been used as a conduit for the flexible fiberoptic bronchoscope in both awake and anaesthetized patients. Although the internal cross-sectional area of the shaft of the laryngeal mask airway is greater than that of a corresponding tracheal tube, consideration should be given to the increase in resistance to gas flow produced by insertion of the bronchoscope and the requirement for controlled ventilation.

An alternative approach involves the passage of the flexible bronchoscope into the upper airway of a spontaneously breathing patient via either the diaphragm of an angle piece attached to an anaesthetic face mask, or via a second aperture on a modified face mask, such as the Patil Syracuse mask. This technique avoids the problem of a reduced space for ventilation between the internal
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wall of the tracheal tube or laryngeal mask airway and the fibreoptic bronchoscope.

RIGID BRONCHOSCOPE

The original rigid bronchoscopes were open-ended, tapered metallic tubes, available in a variety of sizes. Side-holes down the body of the bronchoscope were incorporated later to allow bilateral lung ventilation when the tip of the bronchoscope was in one of the major bronchi. Further modifications to this basic design led to the development of the rigid ventilating bronchoscopes used in current practice which can use a breathing system or a Venturi system to achieve ventilation.

The rigid ventilating bronchoscope incorporates a sidearm adapter which can be attached to an anaesthetic breathing system (fig. 1). Occlusion of the proximal end of the bronchoscope by an eyepiece allows spontaneous or controlled ventilation to occur through the lumen of the bronchoscope. There is a variable gas leak around the bronchoscope.

The rigid bronchoscope which uses the Venturi principle incorporates a needle within its lumen and runs parallel to its long axis (fig. 2). Release of gas from a high pressure source via the needle entrains environmental gas through the proximal open end of the bronchoscope and allows controlled ventilation to occur through the lumen of the bronchoscope.

In contrast with flexible fibreoptic bronchoscopy, rigid bronchoscopy produces a considerable amount of mucosal stimulation, pressure on soft tissues and requires significant extension of the cervical spine. Consequently, this procedure is almost always performed under general anaesthesia. In children, it is advisable that a laryngoscope is used to expose the vocal cords which may also be sprayed with local anaesthetic solution. Such exposure also allows the endoscopist to introduce the correct size bronchoscope with minimum delay and reduces the chances of trauma to the cords.

Patients are able to breathe or their lungs can be ventilated around the flexible fibreoptic bronchoscope. In contrast, the rigid bronchoscope is hollow and patients must either breathe or undergo ventilation through it. The performance of rigid bronchoscopy under general anaesthesia therefore requires that the responsibility for the management of the airway be shared between the anaesthetist and the endoscopist. The anaesthetist must maintain adequate oxygenation and carbon dioxide elimination during a procedure that inevitably interferes with airway and respiratory function.

ANAESTHETIC TECHNIQUES

Rigid bronchoscopy can be performed in the spontaneously breathing patient under a deep plane of anaesthesia using an inhalation anaesthetic agent. This remains a popular technique in some centres for children and for adults with upper airway obstruction. Meretoja and colleagues have recently compared sevoflurane in oxygen and nitrous oxide with halothane in oxygen and nitrous oxide for induction and maintenance of anaesthesia in infants and children undergoing rigid bronchoscopy or gastroscopy. In the sevoflurane group, induction and recovery times were shorter and there were significantly fewer complications, particularly arrhythmias and laryngeal spasm.

Complications of performing rigid bronchoscopy in spontaneously breathing patients range from laryngeal spasm and bronchospasm caused by inadequate anaesthesia, to hypoventilation as a result of excessive anaesthesia. As a consequence, it is common practice to administer an i.v. anaesthetic agent, a neuromuscular blocking agent and to use intermittent positive pressure ventilation. Anaesthesia is maintained by administration of either an inhalation agent, increasingly sevoflurane or an i.v. anaesthetic agent, increasingly propofol. As the inspired oxygen and inhalation anaesthetic agent concentrations are known with a ventilating bronchoscope but not known using the Venturi system bronchoscope, rigid ventilating bronchoscopy can be performed with either inhalation or i.v. anaesthesia. However, rigid bronchoscopy using the Venturi system is best performed under total i.v. anaesthesia using an \( F_{1O_2} \) of 1.0. Intermittent bolus doses of methohexital, etomidate, thiopental and propofol have been used for this purpose. The problems of using these i.v. techniques include awareness caused by administration of inadequate increments of anaesthetic agent and delayed recovery as a result of
administration of excessive anaesthetic agent. It is preferable, therefore, for all but the shortest procedures, to administer the i.v. anaesthetic agent by continuous infusion. Alfentanil followed by infusion of propofol has been shown to provide satisfactory anaesthesia for bronchoscopy without awareness during the procedure, with a rapid postoperative recovery.45

The haemodynamic responses to rigid bronchoscopy have been the subject of several studies. These responses are qualitatively similar to the responses caused by direct laryngoscopy and tracheal intubation, but may be of greater magnitude and longer duration.82 Significant increases in heart rate, systolic and diastolic arterial pressures follow rigid bronchoscopy after thiopental but not propofol anaesthesia.38 Myocardial ischaemia may occur during general anaesthesia for rigid bronchoscopy with or without the development of significant haemodynamic abnormalities.38,82 The addition of a small dose of an i.v. opioid partially controls the haemodynamic responses caused by rigid bronchoscopy after thiopental but is superfluous after propofol.38 Others use the ultra-short-acting β blocker esmolol to attenuate the responses to both bronchoscopy and endobronchial intubation.74,180 There is no evidence that the use of anticholinergic agents to control airway secretions aggravates the haemodynamic response to rigid bronchoscopy.73,52

Neuromuscular block for rigid bronchoscopy may be produced by a variety of agents. The choice is determined by the anticipated duration of the procedure. The depolarizing agent succinylcholine remains popular for short procedures, although the short-acting non-depolarizing agent mivacurium is a suitable alternative. If bronchoscopy is expected to be prolonged or is to be followed by a surgical procedure, a longer acting non-depolarizing neuromuscular blocking agent may be used.

Administration of a local anaesthetic agent to the vocal cords and trachea before rigid bronchoscopy under general anaesthesia has been recommended to prevent laryngeal spasm after the bronchoscope is removed.18 However, the only study of this practice did not demonstrate any advantage when 4% lignocaine 4 ml was sprayed onto the larynx before bronchoscopy.1 Furthermore, the associated depression of the cough reflex is undesirable, particularly when excessive secretions or haemorrhage develop after bronchoscopy.

Gas exchange in the anaesthetized and paralysed patient may be produced using a variety of methods: (1) apnoeic oxygenation; (2) rigid ventilating bronchoscopy; (3) rigid bronchoscopy with Venturi attachment; (4) high frequency jet ventilation; and (5) use of the Hayek oscillator

(1) Apnoeic oxygenation

Insufflation of oxygen via a catheter placed into the lower trachea is a satisfactory method of maintaining oxygenation in a patient who has been preoxygenated, anaesthetized and paralysed for rigid bronchoscopy.17,29 The technique is limited by the development of progressive hypercapnia and respiratory acidosis, P<sub>ACO2</sub> increasing at a rate of 0.5 kPa (3–5 mm Hg) per minute.23,29,84

(2) Rigid ventilating bronchoscope

The rigid ventilating bronchoscope was developed to provide conditions similar to tracheal intubation.37,69 It incorporates at its proximal end a side port which can be attached to an anaesthetic breathing system, allowing continuous flow of anaesthetic gases and vapours. Occlusion of the proximal end of the bronchoscope by a sliding eyepiece allows spontaneous or controlled ventilation to occur via the lumen of the bronchoscope. There is a variable flow of gas around the distal end of the bronchoscope, compensated for by providing a high fresh gas flow or by packing the laryngopharynx.

The major disadvantage of the rigid ventilating bronchoscope is that the sliding eyepiece must be removed during surgical manoeuvres such as suctioning or obtaining biopsy specimens. These interruptions to ventilation inevitably result in progressive hypercapnia and respiratory acidosis when the rigid ventilating bronchoscope is used in the anaesthetized, paralysed patient.52,58 Pollution is also a problem as scavenging is almost impossible with this system.

(3) Rigid bronchoscope using the Venturi principle

The first rigid bronchoscope using the Venturi principle was described by Sanders in 1967.70 He developed an attachment applied to the proximal end of an open bronchoscope which used the energy of compressed oxygen exerted through an injection needle placed inside and running parallel to the long axis of the bronchoscope. Environmental air was entrained by the Venturi effect and generated a pressure within the bronchoscope sufficient to inflate the lungs with a variable oxygen–air mixture. A pressure regulator was required to maintain a constant pressure and the flow was controlled by a manually operated on–off valve placed in the line connecting the pressure regulator to the attachment. Uninterrupted controlled ventilation could be achieved without occlusion of the open end of the bronchoscope and without interference with vision or instrumentation through the bronchoscope. Sanders stated that the use of this device maintained oxygenation without producing hypercapnia and respiratory acidosis. This was subsequently confirmed by several detailed studies.2,64,71

Spoerel and Grant established that the pressure produced at the distal end of the bronchoscope by the Sanders device varied with the volume of oxygen flow into the bronchoscope. This is determined by the driving pressure from the reducing valve, the size of the injector needle, and the diameter, length and type of bronchoscope.73 The tidal volumes generated in an individual are thus dependent on the pressure produced at the distal end of the bronchoscope, the size of the leak around the bronchoscope and compliance of the lungs.

To avoid lung barotrauma, it is important to match the volume of oxygen flow into the bronchoscope to the diameter, length and type of bronchoscope in use. This may be achieved by altering either the driving pressure or the size of the injector needle. In practice, it is usual to maintain a constant driving pressure and adjust the size of the injector needle.
Bethune and colleagues determined the maximum pressures generated in the Negus range of bronchosopes with varying sizes of injector needle and a driving pressure equal to the standard oxygen pipeline pressure of 410 kPa. A 16-SWG needle is suitable for adults, a 18-SWG needle for adolescents and a 19-SWG needle for children, infants and neonates. A 14-SWG needle may be required in adults with poor compliance in order to achieve the high inflation pressures necessary to produce adequate tidal ventilation.

Carden, Trapp and Oulton described a modification of the original device in which oxygen was injected through the sidearm of the bronchoscope with little or no air entrainment. Subsequent comparison of this system with the Sanders device has confirmed that the sidearm system delivers much higher oxygen concentrations and therefore, results in high PaO2 concentrations without producing hypercapnia and respiratory acidosis. This system may also be used to deliver a premixed nitrous oxide–oxygen gas mixture.

It is essential when using any bronchoscope with a Venturi system that the proximal end of the bronchoscope remains open to allow entrainment of air during inspiration and escape of gas during expiration. Otherwise, lung barotrauma may result.

(4) High frequency jet ventilation

The use of high frequency ventilators to produce high frequency–low volume ventilation via the sidearm of the rigid bronchoscope has been shown to achieve suitable operating conditions and adequate gas exchange at rates up to 300 bpm. The technique is popular in some countries, but is not widely used in the UK.

(5) The Hayek oscillator

Rigid bronchoscopy has been performed under general anaesthesia with muscle paralysis and external negative pressure ventilation produced by the Hayek oscillator. There would appear to be no detriment to gas exchange in the lungs. In addition, the endoscopist had total freedom for the investigation as there are no attachments to the bronchoscope whatsoever. This arrangement would also be of benefit during laser therapy to the respiratory tract.

POSTOPERATIVE CARE

At the end of the procedure, administration of anaesthetic agents should be discontinued, 100% oxygen given and the residual effects of non-depolarizing neuromuscular blocking agents antagonized with an anticholinesterase. If a general anaesthetic has been administered, it is advisable to perform direct laryngoscopy and, if necessary, use a suction catheter to clear secretions, blood or other debris from the upper airway. The bronchoscope is removed from the airway before re-establishing control of the upper airway with either a face mask and oropharyngeal airway, a laryngeal mask airway or insertion of a tracheal tube. In the presence of infection or haemorrhage after a biopsy, the patient should be placed with the bad lung down to protect the good lung until the cough reflex returns. The patient should be allowed to recover by breathing a humidified oxygen-enriched air mixture before transfer to a fully monitored recovery area.

COMPLICATIONS

Complications of flexible fiberoptic and rigid bronchoscopy can be classified conveniently into three groups.

Anatomical

Damage to teeth or dental work is not an uncommon occurrence during bronchoscopy. Direct trauma to other structures in the upper and lower airways may result in haemorrhage, oedema or tumour fragmentation which may compromise the airway. Mucosal perforation may lead to subcutaneous emphysema, mediastinal emphysema or tension pneumothoraces. Such complications are particularly likely during bronchoscopic biopsy. An emergency thoracotomy may be required to repair the damage.

Mucosal disruption leading to subcutaneous emphysema, mediastinal emphysema and tension pneumothoraces may also develop as a consequence of barotrauma. Lung barotrauma is particularly likely to occur if a bronchoscope using a Venturi attachment is used carelessly, especially in children, where the escape of gas around the bronchoscope is limited because of a tight fit of the bronchoscope in the glottis.

Physiological

Arrhythmias are frequent during bronchoscopy. Bradycardia occurs as a vagally mediated response to insertion of the bronchoscope and may necessitate i.v. administration of an anticholinergic agent. Other arrhythmias are the result of catecholamines produced in response to the surgical stimulus. Hypoxia and hypercapnia may contribute to these arrhythmias and should be corrected before specific anti-arrhythmics are administered.

After extubation

The development of upper airway obstruction may complicate the recovery period. The commonest causes are laryngeal spasm, masseter spasm or laryngeal oedema. Management of these complications has been reviewed recently, and algorithms have been proposed for their treatment.

Mediastinoscopy

Mediastinoscopy, originally described by Carlens in 1959, is performed for two major reasons: first, to obtain tissue for histological diagnosis, and second, to stage lung malignancy. A histological diagnosis is very important as a lymphoma is treated with radiation while a thymoma, for example, requires resection. A diagnosis of tuberculosis or sarcoidosis will also lead to correct treatment.

The majority of mediastinoscopies are performed via the neck, entering the mediastinum behind the
manubrium—the so-called cervical mediastinoscopy. The second, and less common approach, is through the second left interspace (the anterior approach) to inspect the lower left mediastinum. The former approach is more difficult and has a greater complication rate for several reasons.

- Compression of the trachea and major blood vessels by the mediastinoscope, particularly on the right side. This may lead to a decrease in both venous return and flow to the right carotid and subclavian arteries.
- Torrential haemorrhage from biopsy sites which can lead to acute exsanguination requiring emergency thoracotomy. The main reason for such an event is that as the mediastinal glands enlarge, blood vessels become stretched over them and can appear as an integral part of the mass. Biopsy can cause blood vessels to divide, the cut ends part and bleed profusely into the mediastinum. Furthermore, it may prove difficult to replace blood loss from cannulation sites in the arms and upper body as any fluids used during resuscitation pour into the mediastinum. Hence, it is mandatory to have: two large venous cannulae, one in the arm and the other in the leg; and at least 2 u. of crossed matched blood in theatre before the operation commences.

Other complications that may arise from either approach have been summarized by Benumof (Table 1).

### Table 1 Major complications of mediastinoscopy (by kind permission of J. L. Benumof)

<table>
<thead>
<tr>
<th>Haemorrhage</th>
<th>Pneumothorax</th>
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<tr>
<td>Recurrent laryngeal nerve injury</td>
<td>Air embolism</td>
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<tr>
<td>Compression of vessels</td>
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<tr>
<td>a. Aorta → reflex bradycardia</td>
<td>b. Innominate artery</td>
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<tr>
<td>Right carotid → hemiparesis</td>
<td>Right subclavian → loss of right radial pulse</td>
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<tr>
<td>Compression of trachea</td>
<td></td>
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<tr>
<td>Infection, tumour spread</td>
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Standard haematological and biochemistry investigations in addition to arterial blood-gas tensions and basic lungs function tests should be available. Computed tomographical scans of the neck, thoracic inlet and chest have superseded the older imaging techniques.

### PREMEDICATION

A variety of premedications have been used with few adverse effects, although light oral premedication with a benzodiazepine is currently favoured. No premedication is given in the presence of tracheal compression.

### ANAESTHETIC TECHNIQUES

Mediastinoscopy can be performed under sedation and local analgesia but this is generally no longer practised.

The ideal general anaesthetic should produce profound depression of laryngeal and tracheal reflexes followed by rapid recovery. Whichever technique is used, it is essential that minimum monitoring is established. The arterial pressure cuff however, is always applied to the right arm. The right radial artery can also be cannulated under local anaesthesia to provide a continuous display of arterial pressure. Thereafter, the techniques depend on the clinical condition.

### Mediastinoscopy in a patient with no symptoms or signs

Preoxygenation is followed by i.v. induction using propofol. A short-acting neuromuscular blocking agent such as vecuronium is given. The cords may be sprayed with lidocaine and the anaesthetist intubates the trachea with a reinforced tracheal tube. A short-acting opioid such as alfentanil can be used.

### Mediastinoscopy in the presence of venous congestion

A similar technique can be used but the inflation pressures required to ventilate the patient’s lungs should be kept to the minimum to prevent further undue decreases in venous return. I.v. opioids are best avoided.

### Mediastinoscopy in the presence of respiratory obstruction, myasthenic syndrome, or both

An awake intubation under local anaesthesia is the technique of choice. Alternatively, inhalation induction is used and a reinforced tube introduced into the trachea under deep anaesthesia after the vocal cords have been sprayed with a local anaesthetic agent. An opioid is contraindicated.

### MAINTENANCE

The use of non-depolarizing neuromuscular blocking agents is generally considered essential as the preferred maintenance technique involves intermittent positive pressure ventilation using oxygen, nitrous oxide and a volatile agent. Furthermore, non-depolarizing agents such as vecuronium and...
Atracurium have been used in the presence of myasthenia gravis provided the doses are reduced and neuromuscular activity is monitored using the train-of-four sequence.41 In the future, sevoflurane and remifentanil will possibly be the drugs of choice because of their rapid onset of anaesthesia and rapid recovery. The patient is placed in a slight head-up position to try and reduce congestion in the great veins. Before the start of the surgical procedure, a large venous cannula should be established in the lower limbs.

**Monitoring**

Minimum monitoring is used but arterial pressure in the right arm must be constantly measured for two reasons: (1) to note any compression of the right common carotid artery; and (2) to note any decline in pressure associated with possible blood loss.

The gauge on the ventilator must also be noted for two reasons: (1) to use the lowest pressures compatible with high saturation and normal end-tidal carbon dioxide; (2) to note any acute increases in pressure which are usually associated with tracheal compression.

If compression of either the trachea or vasculature occurs, the surgeon must be informed immediately and told to either remove or reposition the mediastinoscope.

**Complications**

The most serious complication is haemorrhage after a perforated vessel. This can be treated by two methods.

1. The mediastinum can be packed with swabs soaked in a weak epinephrine solution. Vital signs are monitored constantly. If these remain constant, the swabs are removed after 10 min and the mediastinoscope reintroduced to inspect the damage. If the bleeding has stopped, a drain is left in the mediastinum for at least 24 h.

2. If the bleeding continues, arterial pressure begins to decrease and heart rate increases, then a thoracotomy is required. It is recommended that a posterolateral approach is used. Under such emergency circumstances it may be ill advised to replace the reinforced tube with a double-lumen endobronchial tube as this may cause undue delay. In addition, blood for resuscitation and replacement may be better infused via the large venous cannula in the lower limb. The tear or hole in the blood vessel is repaired as rapidly as possible.

Air embolism is an important consideration but is extremely rare as most patients are ventilated artificially. If it does occur and is clinically significant, the patient should be placed in the left head-down lateral position and treated accordingly.

**Postoperative Management**

Neuromuscular block is antagonized, 100% oxygen is given and the tracheal tube removed when appropriate. Patients are transferred to the recovery room, breathing oxygen-enriched air. They receive routine monitoring and are sat up as soon as is possible. Those patients who have had a thoracotomy are managed along the lines set out at the end of this review.

**Oesophagoscopy**

This investigation is performed for three main reasons namely: (1) diagnosis, particularly of carcinoma; (2) removal of a foreign body; and (3) therapeutic, for example injection of oesophageal varices or dilatation of a stricture. Very rarely, it is performed to identify the origin of an oesophageal pouch.

The major problems associated with this investigation are: fluids, blood and solids proximal to the lesion; possible regurgitation of stomach contents; and perforation of the oesophagus.

**Preoperative Preparation**

Many of the patients are elderly, with the additional problems of multiple treatments (e.g. digoxin and diuretics). Furthermore, some of these patients may be dehydrated as a result of dysphagia, and rehydration is required. Recently, however, preoperative chemotherapy has usually enabled many of these patients to be able to swallow and to return to a normal fluid and electrolyte balance.

**Premedication**

It is inadvisable to administer oral premedication. The main reasons are that the drugs may stay in the oesophagus proximal to the lesion and cause retching. Premedication is therefore either avoided or given i.m. Because of possible difficulties in swallowing, antacids are rarely used. However, there are reasonable grounds for using i.v. agents which reduce gastric secretions and increase gastric emptying.

**Induction**

The investigation can be performed under sedation and local analgesia or general anaesthesia.66 Minimum monitoring is mandatory for each procedure.

**Sedation and local analgesia**

There are a variety of techniques available. Most use i.v. sedation (e.g. midazolam) and topical analgesia to the upper respiratory and oesophageal tracts. A fibreoptic oesophagoscope is generally used for inspection and therapeutic procedures. The safety of such procedures has been addressed.66 67 However, the fibrescope cannot be used to remove foreign bodies or in children.

**General anaesthesia**

Several agents have been used to induce anaesthesia after a suitable period of preoxygenation. A rapid sequence technique is used with succinylcholine and cricothyroid pressure. The trachea is intubated with a reinforced tube which is moved to the left side of the mouth to permit passage of either a rigid or flexible oesophagoscope. The rigid variety can compress...
a standard tracheal tube. Most anaesthetists do not wait for the action of succinylcholine to “wear off” before giving a short acting non-depolarizing neuromuscular blocking agent. The reason for this approach is that coughing can increase the chances of the major complication of this procedure namely, oesophageal perforation. Inflation pressures are monitored continuously but additional vigilance is required in children during oesophagoscopy as there are no suitably sized reinforced tracheal tubes available. On rare occasions, when an oesophageal pouch is present, a CT scan is mandatory so that the anaesthetist can position the patient appropriately before induction. The patient is placed in either the left or right semi-lateral positions with the pouch of the sac lowermost. Occasionally, a full lateral position is required. The object is to contain any fluid or solids in the sac until intubation has been accomplished. Cricothyroid pressure is not effective in containing the contents in the sac. Indeed, some may argue that the manoeuvre itself may compress the sac and cause the contents to enter the pharynx.

MAINTENANCE

Anaesthesia is usually maintained with oxygen, nitrous oxide and a volatile agent using intermittent position pressure ventilation. Continuous i.v. propofol is also an acceptable technique. The use of i.v. opioids is optional. Two key monitors are: (1) the ECG, which can show the occasional arrhythmia which is generally not significant; and (2) inflation pressures, which must be monitored continuously to detect compression of the tracheal tube.

POSTOPERATIVE MANAGEMENT

Neuromuscular block is antagonized and 100% oxygen is administered until spontaneous ventilation returns. The trachea is normally extubated in the head-down left lateral position. Patients are transferred to the recovery room breathing oxygen-enriched air. A chest x-ray is always obtained to ensure that there has been no oesophageal perforation. Most surgeons do not allow their patients to drink any fluids for 12 h, some even for 24 h, and maintain hydration by the i.v. route.

Thoracoscopy

PRINCIPLES

The first series of thoracoscopy cases were reported in 1921. The Swedish physician, Jacobaeus, used the technique to treat pulmonary tuberculosis and pleural effusions. The development of antibiotics to treat tuberculosis led to virtual cessation of thoracoscopy. Recent advances in endoscopic surgical equipment and refinement of surgical techniques have expanded the role of thoracoscopy to include multiple procedures that previously could only be performed by open thoracotomy. The major cause of morbidity after thoracotomy is the incision and associated spreading of the ribs even in limited and muscle-sparing procedures.

Thoracoscopy provides access to the thoracic cavity, is associated with reduced morbidity and does not appear to compromise the procedure. Subsequent studies have confirmed reduced postoperative pain, faster recovery to preoperative functional status and reduced hospital stay after procedures ranging from lung biopsy to lobectomy.

Thorascopic procedures are currently used to aid the diagnoses of pleural, lung and oesophageal disease, and to assess the extent of lung trauma. Therapeutic uses include lung resection, laser ablation of emphysematous bullae, oesophageal resection, pericardectomy, sympathectomy, removal of mediastinal masses and some spinal surgery. The anaesthetist is therefore faced with establishing one-lung anaesthesia, the associated complications and the potential for a “minimally invasive”, but often lengthy, procedure, which may be rapidly converted into an open thoracotomy.

PATIENT CHARACTERISTICS

It is often high-risk patients who are referred for thoracoscopy with the assumption that the procedure produces less physiological trespass. Barker and colleagues anaesthetized 40 such patients for thorascopic laser ablation of emphysematous bullae. The patients were elderly smokers with a high incidence of cardiovascular disease who were “respiratory cripples” with little or no exercise tolerance. They tolerated one-lung ventilation better than expected and had stable haemodynamics. However, they did not have prolonged perioperative courses.

PREOPERATIVE PREPARATION

Preoperative preparation involves stopping smoking, hydration, chest physiotherapy, bronchodilators, antibiotics and possibly steroids. Instruction in the use of incentive spirometry and psychological reassurance are also important, in addition to information on possible methods of postoperative analgesia, such as patient-controlled analgesia. The possibility of proceeding to a thoracotomy should be discussed. Current medications, with the exception of insulin, are continued until the morning of surgery. Benzodiazepines are commonly used to produce anxiolysis and sedation.

MONITORING

The early thorascopies were relatively short procedures requiring only brief periods of one-lung ventilation, using basic monitoring. However, as thoracoscopy evolved and became more complex, the procedure has become more similar to thoracotomy in terms of length and duration of one-lung ventilation (OLV). Thus monitoring similar to that used for thoracotomy is routine. This includes ECG pulse oximetry, arterial cannulation for invasive arterial pressure monitoring and blood-gas sampling. Temperature, peripheral nerve block and end-tidal carbon dioxide monitors should also be used. Procedures used to treat pericardial disease or pericardial tamponade may be augmented by transoesophageal echocardiography. However, there are currently no guidelines for additional monitoring requirements for thoracoscopy, Hartrey, Posskitt and Durkin and Fredman, Osflanger and Jedeikin reviewed patients...
undergoing transthoracic endoscopic sympathectomy using one-lung anaesthesia with non-invasive monitoring, and described it as a safe and effective technique. However, their patients were relatively healthy, unlike many patients requiring thoracoscopy, thus highlighting the need to assess each patient individually.

CHOICE OF ANAESTHESIA

Thoracoscopy may be performed under local, regional or general anaesthesia, depending on the proposed procedure, the technical abilities of the anaesthetist and surgeon, and the patient’s physical and psychological state. Local anaesthetic infiltration of the lateral thoracic wall and the parietal pleura is the simplest method of providing analgesia. Intercostal nerve or thoracic extradural blocks provide more complete analgesia, supplemented with ipsilateral stellate ganglion block to inhibit the cough reflex stimulated by manipulation of the hilum. Advantages of local techniques are the ability to have an awake, spontaneously breathing patient who is able to cough after operation and has good analgesia. Menzies and Charbonneau showed that diagnostic thoracoscopy for pleural disease under sedation and local anaesthesia was a feasible and safe procedure. The spontaneously breathing patient with an open chest in the lateral decubitus position may have impaired gas exchange as a result of paradoxical respiration and mediastinal shift. It is therefore important to keep the surgical procedure short and simple and always administer supplementary oxygen. General anaesthesia is therefore far more appropriate for most modern thoracoscopies. Intermittent positive pressure ventilation reduces the changes associated with mediastinal shift and prevents paradoxical respiration. It also allows easier monitoring of ventilation. General anaesthesia for thoracoscopy is an indication for the placement of a double-lumen endobronchial tube allowing lung deflation, safe insertion of trocars and provides a better view of the operative side. The lung can be re-expanded under direct vision to assess air leaks or adhesions.

INDUCTION

The anaesthetic technique is tailored to the individual patient. Anaesthesia is induced with either thiopental, etomidate or propofol, and neuromuscular block is provided by vecuronium, atracurium or pancuronium, depending on the proposed length of the procedure. Anaesthesia is maintained with an inhalation agent or continuous infusion of propofol. Opioids can be given to provide analgesia and supplement anaesthesia. Regional and general anaesthesia may be combined to allow a lighter general anaesthetic to be given and to provide postoperative analgesia.

ONE-LUNG ANAESTHESIA

Intermittent positive pressure ventilation in the anaesthetized, paralysed patient with an open chest in the lateral decubitus position can overcome the problems of mediastinal shift and paradoxical respiration encountered in the awake patient. However, there may still be considerable ventilation-perfusion mismatch. Pulmonary blood flow continues to be governed by gravity and changes in resistance in the vasculature, particularly in the non-dependent lung. Ventilation to the dependent lung is reduced because of loss of the dependent lung volume with anaesthesia, compression by mediastinal and abdominal contents, and suboptimal positioning. In addition, poor mucociliary clearance and absorption atelectasis is caused by the increased fraction of inspired oxygen used during one-lung ventilation.

Several techniques are available to achieve one-lung ventilation. The most common uses a double-lumen endobronchial tube (DLT). Many anaesthetists prefer to use left-sided DLT because of the ease of placement and greater margin of safety. Misplacement of a right-sided DLT introduces the risk of inadequate ventilation to the right upper lobe. Fibreoptic bronchoscopy has revealed malpositioning in 48% of cases even though the double-lumen tube was thought to be in the correct position based on clinical signs. When the position of the DLT is confirmed only on the basis of clinical signs, there may be intraoperative problems with either deflating the non-dependent lung or completely separating the two lungs in 25% of the cases. Confirmation of correct position is by fibreoptic bronchoscopy after the initial intubation and again when turned into the lateral decubitus position. During one-lung ventilation any blood flow to the non-ventilated lung becomes part of the shunt flow. Consequently, for the same $F_{O_2}$, haemodynamic and metabolic status, one-lung ventilation results in a much larger alveolar–arterial oxygen tension difference and lower $P_{A_{O_2}}$ than two-lung ventilation.

One-lung ventilation has much less effect on $P_{A_{CO_2}}$ than on $P_{A_{O_2}}$. The ventilated lung can eliminate enough carbon dioxide to compensate for the non-ventilated lung. However, it cannot take up enough oxygen because of the plateau at the top end of the oxygen–haemoglobin dissociation curve. There are both passive and active mechanisms operating during one-lung ventilation that reduce blood flow to the non-dependent, non-ventilated lung. Passive mechanisms include gravity, surgical interference and the extent of pre-existing disease in the non-dependent lung. Hypoxic pulmonary vasoconstriction causes the most dramatic reduction in blood flow to the non-dependent lung by an active vasoconstrictor mechanism. The selective increase in pulmonary vascular resistance of the collapsed lung diverts blood flow towards the remaining ventilated lung.

MANAGEMENT OF ONE-LUNG ANAESTHESIA

One-lung ventilation carries a risk of hypoxaemia. It is therefore important to optimally manage ventilation. $F_{O_2}$ should be increased to 0.5 or 1.0 if required to maintain arterial oxygen saturation ($S_{O_2}$) greater than 90%. The benefits of ventilating the dependent lung with 100% oxygen far exceed the theoretical risks of absorption atelectasis and oxygen toxicity. The dependent lung should be ventilated with a tidal volume of approximately 10 ml kg$^{-1}$ with close monitoring of airway pressures. Ventilatory frequency is adjusted to maintain $P_{A_{CO_2}}$ at 5.3 kPa (40 mm Hg). If there is a
problem with ventilation, the correct position of the double-lumen endobronchial tube should be confirmed with the fiberoptic bronchoscope. If hypoxaemia persists, differential lung ventilation should be instituted. Continuous positive airway pressure (CPAP) maintains the patency of the non-dependent lung airways allowing some oxygen distension of the alveolar spaces involved with gas exchange. Because the volume of the ventilated dependent lung is often decreased during one-lung ventilation, many attempts have been made to improve oxygenation by selectively treating this lung with positive end-expiratory pressure (PEEP).

An accepted risk is that PEEP-induced increase in lung volume can cause compression of the intra-alveolar vessels of the small dependent lung and increase pulmonary vascular resistance. Blood flow may then be diverted from the ventilated to the non-ventilated lung, thereby increasing the shunt and decreasing $P_{aO_2}$. If oxygenation does not improve with CPAP 5 cm H$_2$O delivered to the non-dependent lung, PEEP 5 cm H$_2$O is added to the dependent lung. These pressures can be increased sequentially in search of the maximum compliance and a minimum right-to-left shunt.$^7$ Resumption of two-lung ventilation is the quickest way to improve oxygenation.

Chest drains are inserted at the end of surgery and connected to underwater drainage systems. In all but the most frail patients, the trachea should be extubated at the end of the procedure and monitored closely in a high dependency unit.

**COMPLICATIONS**

Haemorrhage is a rare complication of thoracoscopy. Bleeding may be rapid and profuse. Therefore, a large bore venous cannula should be sited before operation. Blood should be available for rapid transfusion. Hypotension may result from cardiac arrhythmias, pulmonary embolus or myocardial infarction. Perforation of organs is rare. The anaesthetist should be aware of potential damage to the heart, pericardium, lungs, oesophagus and the sympathetic chain. Occasionally surgeons insufflate the pleural cavity with carbon dioxide via a Verres' needle which increases the risk of perforation of organs and may result in arterial carbon dioxide embolism. Haemodynamic instability is reported by some not to be a problem if the volume of gas is limited to 2 litre and insufflated slowly. However, Hill and colleagues$^9$ studied haemodynamic changes with positive pressure insufflation of carbon dioxide during OLV in pigs. They demonstrated significant haemodynamic compromise at pressures of 5 mm Hg and greater. A capnotherax has been described in humans which has also demonstrated that there are consequent adverse haemodynamic changes.$^{68}$

Complications related to OLV include hypoxia most commonly caused by malposition of the DLT. During long procedures fluid may collect in the lower lung, particularly if generous i.v. fluids have been given, which further impair gas exchange. Bronchial rupture after over inflation of the bronchial cuff of the DLT is also a rare complication.

When securing the patient in the lateral decubitus position, care must be taken to avoid any nerve injury and to ensure that there is enough room for respiratory excursion. Finally, if laser therapy is used, ventilation with 100% oxygen must be seriously considered as a potential fire hazard.

**POSTOPERATIVE MANAGEMENT**

Thoracoscopy patients are spared a great deal of postoperative pain and respiratory dysfunction, leading to reduced morbidity and shortened hospital stay. However, these patients still require concerted efforts to minimize complications. A variety of techniques can be used to help reduce postoperative pulmonary complications. Incentive spirometry is an ideal respiratory care manoeuvre. Ensuring the patient sits upright in bed and early ambulation augments the FRC and helps restore a favourable FRC-closing volume relationship thus preventing further atelectasis. Percussion and postural drainage aid in the mobilization of secretions and continuing administration of bronchodilating drugs or steroids that were given before operation is important in maintaining reactive airways quiescent.

**Treatment of postoperative pain**

Thoracoscopy results in much reduced postoperative pain compared with thoracotomy. Pleural drainage time is also less.$^{56}$ Local anaesthetic solutions are often infiltrated into the incisions and pleural cavity, although there is some doubt whether the latter is effective.$^8$ Post-thoracoscopy pain can be treated by systemic administration of opioid and potent non-steroidal anti-inflammatory drugs.

Parenterally administered analgesics are usually necessary to relieve pain related to chest drains. Patient-controlled analgesia is also an efficient method. Regional analgesia is usually unnecessary in patients who have undergone simple thoracoscopy procedures but provides superior pain relief when used. Extradural analgesia confers the most benefit as it treats both the chest drain and incisional pain, and this improves pulmonary function.

In summary, anaesthesia for surgical telescopic procedures of the thorax has become more refined. Each procedure has certain but different anaesthetic considerations with the one common denominator being that all could be followed by thoracotomy. All medical and nursing staff should be aware of this possibility and be prepared if required to proceed immediately.

**References**

Anaesthesia for telescopic procedures in the thorax


