Anaesthesia for surgery of the trachea and main bronchi

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Abstract
Major surgery on the trachea and airway is an anaesthetic challenge, which necessitates the simultaneous control of the airway, maintenance of gas exchange and good surgical exposure. Advance planning, good communication and teamwork among surgeon, anaesthetist and theatre nurses are never more important. A major indication for laryngeal and tracheal surgery is laryngotracheal stenosis, a rare condition, which can cause significant morbidity and life-threatening airway obstruction. In the era of modern medicine, post-intubation injury has superseded infection and external trauma as the commonest aetiology. Definitive surgery is usually carried out in tertiary specialist centres, where segmental resection of the trachea with primary end-to-end anastomotic reconstruction is usually the technique of choice. Provision of anaesthesia for bronchial sleeve resection and removal of inhaled foreign bodies faces similar challenges.

Keywords airway; anaesthesia; stenosis; surgery; trachea

Tracheal anatomy
This is described elsewhere (see pages 533–538, in this issue).

Laryngotracheal stenosis
The major causes of laryngotracheal stenosis are listed in Table 1. Post-intubation benign stricture is the commonest indication for tracheal resection and is typically a consequence of prolonged tracheal intubation or tracheostomy. When the cuff of the tracheal tube exerts a tracheal wall pressure in excess of the capillary perfusion pressure of the tracheal mucosa then ischaemic injury will result. Severe or recurrent tissue injury results in ulceration, chondritis, granulation tissue formation and, over time, concentric fibrotic contraction and airway narrowing. Direct injury from the tracheal tube wall may also result in granuloma formation and artenoidal cartilage damage. Modern high-volume, low-pressure cuffs have lowered the risk of tracheal stricture, and the total number of patients surviving prolonged intubation has increased.

Learning objectives
After reading this article, you should be able to:
- describe the aetiology and presentation of laryngotracheal stenosis
- discuss the central role of rigid bronchoscopy in airway assessment
- compare the airway management for upper and lower tracheal resection

Traction on the tube and local infection also contribute to the development of stenoses. Suprastomal stricture is a recognized late complication of both open surgical and percutaneous tracheostomy. A summary of the features of presentation of tracheal stenosis is provided in Table 2.

Investigation
A previous history of tracheal intubation or tracheostomy should alert the clinician to the possibility of tracheal stenosis, which is often not evident on plain posteroanterior and lateral radiographs. Computed tomography (CT) or magnetic resonance imaging (MRI) scans demonstrate tracheal narrowing but may not accurately determine the exact length and position. Three-dimensional reconstructions of the tracheobronchial anatomy are providing surgeons with additional information to guide surgery.

Spirometric flow–volume loops (see pages 539–541, in this issue) were historically important in the diagnosis of intrathoracic airway obstruction. They are now generally not instrumental in

Aetiology of adult laryngotracheal stenosis

<table>
<thead>
<tr>
<th>Category</th>
<th>Cause</th>
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<tbody>
<tr>
<td>Post-tracheal intubation</td>
<td>Cuff-related circumferential stricture</td>
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<tr>
<td></td>
<td>Granuloma, artenoidal injury</td>
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<tr>
<td>Post-tracheostomy</td>
<td>Stomal stricture</td>
</tr>
<tr>
<td>Trauma</td>
<td>Penetrating or blunt external trauma</td>
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<td>Irradiation and burns</td>
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<tr>
<td>Benign neoplasm</td>
<td>Respiratory papillomatosis</td>
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<tr>
<td></td>
<td>Carcinoid tumour</td>
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<td>Malignant neoplasm</td>
<td>Primary: adenoid cystic and squamous carcinoma</td>
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<td></td>
<td>Secondary: thyroid carcinoma</td>
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<td></td>
<td>Metastatic</td>
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<tr>
<td>Chronic inflammatory disease</td>
<td>Amyloidosis</td>
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<td>Sarcoidosis</td>
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<td>Collagen vascular diseases</td>
<td>Relapsing polychondritis</td>
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<td>Bilateral vocal cord dysfunction</td>
<td>Wegener's granulomatosis</td>
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<tr>
<td>Infection</td>
<td>Bilateral recurrent laryngeal nerve injury</td>
</tr>
<tr>
<td>Idiopathic</td>
<td>Tuberculosis, diphtheria</td>
</tr>
<tr>
<td></td>
<td>Idiopathic progressive subglottic stenosis</td>
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</tbody>
</table>

Table 1
Presentation of tracheal stenosis

- Presents weeks to months after intubation
- Slowly progressive dyspnoea
- Cough and wheeze easily mistaken for asthma
- Inspiratory stridor
- Recurrent pneumonias

Table 2

making a definitive diagnosis, but may be helpful to monitor the progression of airway obstruction after treatment.

Endoscopy is critically important for evaluation of both the larynx and trachea (Figure 1). The larynx may be assessed by indirect mirror examination and flexible nasolaryngeal endoscopy. Because severe tracheal stenosis may deteriorate into complete obstruction during awake flexible bronchoscopy, tracheal stenosis should be defined by rigid bronchoscopy under general anaesthesia. Passage of a rigid bronchoscope can be life saving in cases of central obstruction or extrinsic compression of the airway following induction of anaesthesia. Rigid bronchoscopy also allows full assessment of the lesion, biopsy, if appropriate, and assessment of the health of the surrounding mucosa.

Anaesthesia for bronchoscopy

Either inhalational or intravenous anaesthesia can be used for induction of anaesthesia. Inhalational induction maintains spontaneous ventilation and avoids muscle relaxation until the airway is secured. However, coughing and instrumentation can precipitate complete obstruction in patients with central airway obstruction. In practice, intravenous anaesthesia and muscle relaxation with suxamethonium (succinyl choline) are generally used to rapidly provide surgical anaesthesia to facilitate the passage of a rigid bronchoscope. Administration of short-acting intravenous agents such as propofol and remifentanil ensures a rapid and complete recovery of consciousness. Atmospheric pollution from escape of volatile gases from the open airway during anaesthesia is also avoided. Ventilation is provided through the bronchoscope with a Venturi-type injector. The rigid bronchoscope thereafter ensures a clear airway and ventilation with oxygen-enriched air.

Acute treatment of tracheal stenosis

Severe respiratory difficulty may be treated initially with steroids, nebulized racemic adrenaline, and diuretics, which temporarily improve mucosal oedema and airway obstruction while antibiotics may be required to treat bronchopulmonary infection. Often, benign tracheal stenosis will be dilated to relieve stridor and to allow assessment and optimization of the respiratory status before definitive surgery occurs. Dilatation of circumferential lesions usually provides temporary relief only and restenosis occurs. Results of endoscopic resection of granulomas and other non-circumferential lesions are somewhat better.

Tracheal and bronchial stenting

Airway stents are inserted to provide symptomatic relief for obstructing nonresectable primary airway tumours. Stents may also be of benefit in the management of central airway obstruction as a result of extrinsic compression from goitres, mediastinal masses, thyroid tumours or lymphomas. Stenting may be used as a bridge to curative or palliative treatment. Self-expandable airway stents can be deployed under fluoroscopic control through an otracheal tube. Rigid bronchoscopy provides better visualization and more room within the airway, which allows deployment of all types of stents. General anaesthesia is often required for stent insertion as control of airway reflexes and maintenance of a patent airway are essential.

Laser therapy

Laser treatment of tracheal strictures has variable results and, as with dilatation, the result is usually a temporary measure prior to definitive treatment. A carbon dioxide laser can be used to palliate unresectable airway tumours that are causing central obstruction. Care must be taken to avoid ignition of tracheal masses, thyroid tumours or lymphomas. Stenting may also be of benefit in the management of central airway obstruction. Dilatation of obstructing airway stents can be deployed under fluoroscopic control through an otracheal tube. Rigid bronchoscopy provides better visualization and more room within the airway, which allows deployment of all types of stents. General anaesthesia is often required for stent insertion as control of airway reflexes and maintenance of a patent airway are essential.

Tracheal reconstruction

Surgical techniques

Tracheal resection and primary anastomotic reconstruction is the preferred surgical treatment of severe tracheal stenosis. The number of rings resected depends on the pathology and the length of the lesion. Modern surgical techniques have produced good results with resection of up to half the tracheal rings. The surgical approach can be cervical, cervicomediastinal or posterolateral thoracotomy. A cervical approach to the subglottic and upper trachea is performed through a collar incision. In addition, a partial or full sternotomy may be necessary for access to the intrathoracic portion of the trachea, whereas for good surgical exposure of the lower trachea a right thoracotomy is required. Major complications of the surgery include restenosis, dehiscence, innominate artery erosion and damage to the recurrent laryngeal nerves. Excessive anastomotic tension and devascularization are generally responsible for restenosis and dehiscence and should be avoided. Surgical release procedures such as the
release of the anterior and posterior tracheal tissues, pulmonary ligaments and the larynx can be performed to ease approximation of the tracheal margins. A guardian suture may be placed at the end of surgery that passes from the skin over the mandible to the anterior chest. The suture remains in situ for up to a week after reconstructive surgery and discourages neck extension, thereby limiting tracheal anastomotic tension.

**Airway management**

The airway management should be planned in advance. A variety of sizes of armoured tubes and microlaryngeal tubes (MLTs) may be required. The airway management of an upper or middle tracheal resection is described in Figure 2. A lower tracheal resection can present additional difficulties. These are often approached through right thoracotomy and may require endobronchial intubation and collapse of the right lung to facilitate surgical access. The presence of a double lumen tube would make surgical repair of the trachea impossible. The two commonest techniques of airway management for lower tracheal resection are described in Figure 3. These are endobronchial intubation across the surgical field and the use of bilateral jet ventilation catheters placed into the main bronchi, which allows good surgical access during the critical phase of surgical repair of the trachea. Cardiopulmonary bypass can be utilized to allow full cessation of ventilation; however, the risks of anticoagulation and the harmful effects of cardiopulmonary bypass on the lungs are best avoided. A microlaryngeal (MLT) tube placed in the left main bronchus can be used to secure the airway. The ventilation of both bronchi with two separate ventilators has been also been described for carinal surgery. Follow-up rigid bronchoscopy is

*Figure 2* The airway management of an upper or middle tracheal resection with end-to-end anastomosis.

*Figure 3* The airway management of a lower tracheal resection.
required to assess tracheal suture and airway patency. It may also be indicated for oncological surveillance.

**Anaesthetic technique**

A key objective of tracheal surgery is for the patient to be extubated awake, warm, well oxygenated and cardiovascularly stable at the end of the surgery. Early extubation is preferable as the presence of an endotracheal tube cuff at the tracheal anastomosis may compromise healing. The patient is initially positioned in an extended neck position, which is usually changed at the time of the anastomosis to a more neutral position that reduces the tension on the tracheal anastomosis. The operation may be prolonged, particularly if laryngeal release procedures are required, and may result in significant blood and heat loss. Attention to fluid balance and maintenance of normothermia with warmed fluids and heated blankets is essential for successful extubation. The anaesthetic technique must ensure that the risk of residual hypnosis, muscle relaxation and excessive opiate-related narcotics is minimized. Adequate analgesia must, however, be provided. The anaesthetic technique may at times be required to accommodate an unprotected open airway, although these periods should be minimized. For these reasons the authors consider total intravenous anaesthesia with propofol and remifentanil as the technique of choice. Epidural analgesia may be used for pain relief after thoracotomy or sternotomy, but is not essential.

At the end of surgery, the patient is awakened and, where possible, the trachea is extubated. A guardian suture is often used to restrict neck extension. The patient is monitored in a critical care environment, which allows early detection of airway difficulties. Intensive physiotherapy and early mobilization are important ways of minimizing the risk of postoperative respiratory complications. Steroids are not routinely used as they may impair healing of the tracheal anastomosis.

**Sleeve lobectomy and bronchial sleeve resection**

A sleeve lobectomy is the excision of a pulmonary lobe along with a circumferential sleeve of mainstem bronchus, while a sleeve resection is the excision of a sleeve of bronchus with sparing of the lung parenchyma. Sleeve lobectomy is indicated in the management of bronchial carcinomas that extend into the lobar bronchus or the adjacent mainstem bronchus (Figure 4). It has a well-established role in patients considered to have inadequate cardiopulmonary reserve to tolerate a pneumonectomy but may be considered in any case of bronchial carcinoma that can be adequately resected by this technique. Additional indications for sleeve lobectomy or resection include bronchial carcinoid and benign bronchial strictures. Airway management for sleeve lobectomy is generally provided with a standard double lumen tube to allow one lung ventilation (Figure 5). Anaesthesia follows the same principles as described for the management of tracheal resection.

**Inhaled foreign body**

The inhalation of a foreign body generally occurs in small children and vulnerable adults with either disabilities or drug-induced depression of conscious level. Presenting symptoms may be stridor, cough, recurrent pneumonias or respiratory

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**Figure 4** Bronchial carcinoma of the right upper lobe extending into the mainstem bronchus.

**Figure 5** (a) Intubation with a left-sided double lumen tube allows selective collapse of the right lung for optimal surgical access. (b) Illustrates resection of right upper lobe with associated sleeve of main bronchus.

**Figure 6** A ventilating Storz paediatric bronchoscope with Jackson Rees modification of the Ayre’s T piece.
difficulty. Chest radiograph may reveal collapse consolidation distal to the obstructed bronchus or emphysematous distension due to a ball-valve effect of the obstructing foreign body. Rigid bronchoscopy under general anaesthesia is undertaken for investigation and removal of any foreign body. If the respiratory status allows, in children, spontaneous ventilation should be maintained with the ventilating bronchoscope and Jackson Rees T-piece to avoid dislodging any foreign body distally (Figure 6). If necessary, controlled ventilation can be provided with this attachment also. The alternative school of thought is that any foreign body that requires bronchoscopic removal is impacted and unlikely to be displaced by controlled ventilation. In adults, Venturi-type jet ventilation such as the Sanders injector is used. Postoperative mucosal oedema and secretion clearance may be problematic.

Conclusion

Tracheal and airway surgery presents a unique anaesthetic challenge. This type of surgery will generally be performed in specialist centres; however, the principles of airway management are universal. Rigid bronchoscopy is of crucial importance for airway management and assessment. The commonest indication for tracheal resection is now post-intubation and tracheostomy stenosis.

FURTHER READING