SEARCH STRATEGY

The data in this chapter are supported by a PubMed search using the key words difficult intubation, difficult airway, obstructed airway.

DEFINITIONS

The difficult airway is the clinical situation in which a practitioner experiences difficulty with adequate maintenance and/or protection of the airway. Three airway devices are in common use – the face mask, laryngeal mask and tracheal tube – and each offers a different level of airway protection and maintenance. A cuffed tracheal tube offers the highest level and for this reason is prominent in airway management plans in head and neck surgery.

Two broad airway problems can be defined, difficult ventilation and difficult intubation. Difficult mask ventilation was defined by the American Society of Anesthesiologists (ASA)\(^1\) as the inability to maintain the oxygen saturations above 90 percent by face mask inflation with 100 percent inspired oxygen or to reverse signs of inadequate ventilation. Oxygen stores in the body are exhausted within a few minutes and difficult or failed ventilation will rapidly result in morbidity or mortality from hypoxaemia. Difficult intubation was defined by the ASA as the inability to complete tracheal intubation within three attempts at direct laryngoscopy or within ten minutes. Provided that face mask ventilation is possible, failed tracheal intubation by itself should not result in hypoxaemia unless the failure of airway protection leads to gross airway soiling from gastric contents or blood. Unfortunately, failed tracheal intubation is, in clinical practice, associated with the problems of unrecognized oesophageal intubation, damage to the airway and hypoxaemia.

Difficult intubation may be defined by the number of attempts at direct laryngoscopy or time to achieve intubation, but also by the view of the laryngeal structures seen at direct laryngoscopy. Cormack and Lehane\(^2\) described the commonly used classification of the best view of laryngeal structures seen at direct laryngoscopy. Grade I is visualization of the entire laryngeal aperture, grade II is visualization of the posterior portion of the laryngeal aperture, grade III is visualization of the
epiglottis only and grade IV is no view of any laryngeal structures. Difficult laryngoscopy (and therefore difficult intubation) indicates that it is not possible to see any portion of the vocal cords (grade III/IV) after multiple attempts at conventional direct laryngoscopy. A final method of defining difficult intubation is through the need for specialized equipment, often taken as requiring an intubation device other than the standard Macintosh or straight-blade laryngoscope. This has some practical significance because when an anaesthetist fails to intubate by direct laryngoscopy (equipment present in each operating theatre) it is often necessary to use equipment from a difficult intubation trolley located centrally in a theatre complex.

Difficult direct laryngoscopy is only one cause of difficulty with intubation. It may be easy to visualize the larynx but intubation is unsuccessful because the larynx, subglottis or trachea are abnormally narrowed or distorted.

**PREVALENCE**

Both difficult intubation and difficult ventilation are uncommon. The prevalence of Cormack and Lehane laryngoscopic grade III is 1.5 percent in the general population. Requiring more than three attempts at direct laryngoscopy occurs in approximately 0.4 percent patients and the average anaesthetist will abandon intubation in approximately 1:2500 general surgical patients. In 1200 consecutive ENT and general surgical patients the overall prevalence of difficult intubation (defined as requiring specialist equipment) was 4.2 percent. The highest prevalence was 12.3 percent in ENT cancer surgery, 3.5 percent in ENT noncancer surgery and 2.0 percent in general surgical patients. This confirms the clinical impression that difficult intubation is more common in patients undergoing head and neck surgery, particularly in those patients following extensive surgery, flap reconstruction and postoperative radiotherapy or with an obstructed airway.

It is difficult to know the precise prevalence of difficult face mask ventilation. Catastrophic failure leading to serious morbidity or mortality is generally quoted as 1:10,000–1:100,000. However, in any large series, a number of problem patients are identified preoperatively and do not receive a general anaesthetic. A North American study involved 18,500 patients of whom 18,200 were intubated under general anaesthesia with 1.8 percent requiring more than two attempts at direct laryngoscopy and no patient being impossible to mask ventilate. Approximately 300 patients underwent awake intubation and it is this group of patients that is likely to contain those who would have proved difficult to ventilate if anaesthetized. A study of 1502 patients determined a prevalence of difficult mask ventilation of 5 percent but the definition used was that the anaesthetist considered the difficulty was clinically relevant and could have led to potential problems if mask ventilation had to be maintained for a longer period.

**EVALUATION**

The aim of airway management is to adequately maintain and protect the airway by use of the face mask, laryngeal mask or tracheal intubation, and preoperative evaluation seeks to initially determine which airway device is required and whether there will be any difficulties in the use or insertion of it. The face mask provides no airway protection and is little used in anaesthesia for head and neck surgery, except for operations such as insertion of grommets. The decision as to whether to use the laryngeal mask or tracheal intubation is taken after considering such factors as the length of surgery, surgical access, requirement for positive pressure ventilation and risk of airway soiling from either blood, pus, cerebrospinal fluid or gastric contents.

The airway may be evaluated according to the scheme outlined in Table 39.1.

**History**

The anaesthetic or hospital notes may indicate previously encountered difficulty with airway management. The patient may pass on verbal or written information from a previous anaesthetist that they are difficult, or difficulty may be inferred from a history of displaced front teeth, bruised lips, excessive sore throat or an unexpected stay in ITU. Past surgery or radiotherapy, or the current surgical condition, may be relevant if it affects the head, neck or mediastinum. A number of medical conditions, such as rheumatoid arthritis, obstructive sleep apnoea and acromegaly, have some association with difficult airway management. In a prospective study of 128 patients with acromegaly, laryngoscopy was difficult (laryngoscopic view grade III) in 10 percent. This indicates that the prevalence is six to eight times higher than in normal patients but 90 percent of acromegalics are still easy to intubate. There are a number of congenital

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Relevant</th>
<th>Possible</th>
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</thead>
<tbody>
<tr>
<td>History</td>
<td>Previous airway difficulty</td>
<td>Previous surgery</td>
</tr>
<tr>
<td>Antecedents</td>
<td>Current surgical condition</td>
<td>Current medical condition</td>
</tr>
<tr>
<td>Examination</td>
<td>General</td>
<td>Specific predictive tests</td>
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<tr>
<td>Investigations</td>
<td>MR imaging</td>
<td>CT imaging</td>
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<tr>
<td></td>
<td>Flow-volume loop</td>
<td>Flexible nasendoscopy</td>
</tr>
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</table>
conditions, such as Treacher-Collins and Pierre-Robin, in which airway management, particularly intubation, is often difficult. Figure 39.1 illustrates a patient with Hunter’s syndrome in which abnormal mucopolysaccharide is deposited in the tissues. Characteristically, he was difficult to intubate for a tonsillectomy to alleviate obstructive sleep apnoea and required an emergency tracheostomy in the recovery period. He is pictured in his late teens when his original standard tracheostomy tube had been replaced by one designed to circumvent lower tracheal and carinal deposits. This T-Y silastic stent passes from just below the vocal cords into each main bronchus (an inverted Y shape) with a limb passing out through the tracheostomy (the T component).

**Examination**

General examination of the patient looks for the features in the following list and the practitioner may be alerted to possible difficulties by various findings:

- trauma, burn, swelling, infection, scarring, haematoma of the mouth, tongue, larynx, trachea or neck;
- large tongue, receding jaw, high-arched palate, prominent upper incisors, short thick neck, large breasts, microstomia, fixed larynx, impalpable cricothyroid membrane, limited mouth opening, limited head/neck movements;
- voice change, shortness of breath, stridor, inability to lie down.

A number of these factors, such as the appreciation of a short neck or receding jaw (Figure 39.2), are subjective. This does not diminish their importance since professional judgements may often be subjective. However, there is a vast literature on prediction of difficult intubation by specific or objective tests. A number have been introduced and the five tests most commonly used are gape, jaw slide, thyromental distance, Mallampati and atlanto-occipital movement.

**Gape**

Gape is the measurement of maximal mouth opening and is usually expressed as interincisor distance in finger-breadths or centimetres. Normal values are 3 fb or 5 cm. A mouth opening of 2 fb is limited and 1 fb is severely limited making direct laryngoscopy very difficult. It is difficult to insert a laryngeal mask when the gape is less than 1–1.5 cm (Figure 39.3).

**Jaw Slide or Mandibular Protrusion**

Functions are graded as follows: class A if the lower jaw can be protruded beyond the top teeth; class B if the lower...
teeth can only reach the top teeth; and class C if the lower teeth will not reach the top teeth. The value of testing this function is that, in intubation by direct laryngoscopy, the lower jaw must slide forward. In some scoring systems, mouth opening and jaw slide are combined, the greatest difficulty indicated by a gape of <3.5 cm and class C jaw slide. Another method of testing mandibular protrusion is the upper lip bite test\(^8\) in which the patient demonstrates how much of the upper lip may be covered by the lower incisors. Class 1 indicates 'biting' above the vermilion line, class 2 below the vermilion line and class 3 inability to bite the upper lip.

**THYROMENTAL DISTANCE**

This measurement, described by Patil, is from the mentum to thyroid notch in full neck extension. The normal measurement is 6–7 cm or 3 fl (Figure 39.4). A short distance (2 fl) indicates a 'high' larynx and difficult direct laryngoscopy.

**MALLAMPATI**

Mallampati’s contribution was a test to assess oropharyngeal space. The test asks a seated patient to open their mouth fully and extend the tongue maximally. The practitioner notes which posterior pharyngeal structures are visible. Mallampati described only three grades: class 1 indicates that the posterior pharyngeal wall, fauces and uvula are visible; class 2 indicates that only a part of the fauces, posterior wall and uvula are visible; and class 3 indicates that the tongue meets the palate. Samsoon and Young arbitrarily introduced a subdivision of class 3 (tongue against soft palate) and class 4 (tongue meets hard palate).

**ATLANTO-OCCIPITAL MOVEMENT**

Optimal head and neck positioning for direct laryngoscopy requires cervical spine flexion and almost maximal extension of the head on the spine. A simple clinical test to look at atlanto-occipital movement is for the clinician to ask the patient to flex their neck maximally and then nod; the observer’s hand placed posteriorly on the neck makes certain that the nodding motion is at the level of the cranium on the upper cervical vertebrae. Atlanto-occipital extension may be clinically graded as normal or reduced or measured and the normal value is 35°.

**Investigations**

Plain x-rays may demonstrate abnormalities, such as enlargement of the retropharyngeal space (Figure 39.5), a swollen epiglottis, tracheal deviation or narrowing, a radio-opaque foreign body or obstructive emphysema suggesting a ball-valve obstruction in the relevant bronchus. However, imaging of the whole airway by CT or MR scan is better and will show narrowing or distortion and allow planning of airway instrumentation. Flexible nasendoscopy under topical anaesthesia is extremely useful in delineating supra- or glottic pathology, and a longer flexible fibrescope can inspect the whole respiratory tract although generally this requires sedation.

Another useful test is the flow-volume loop. This expresses flow during expiration and inspiration as a function of lung volume. Airflow is measured during inhalation from residual volume to total lung capacity and exhalation back to residual volume. Extrathoracic obstruction causes limitation of inspiratory flow whilst intrathoracic obstruction causes limitation in expiratory flow. Limitation in expiratory flow is particularly noticeable because the highest flow-rates are usually present in peak expiration.
PREDICTION OF DIFFICULTY

The practitioner forms a professional judgement as to whether airway management plans need to be altered from that carried out normally. It is easy to be definite or accurate in prediction when there are ‘barn-door’ abnormalities in the past anaesthetic history, past surgical history, examination and current disease process or from imaging. Examples would be a known history of failed intubation, presentation with breathing difficulty or stridor, absent mouth opening or previous head and neck reconstructive surgery. In a study of 181 patients with pharyngolaryngeal disease,9 the single most predictive factor of difficult intubation was a tumour in the supraglottic region. In a study of 320 patients with a goitre undergoing thyroid surgery,10 the presence of tracheal compression, presence of dyspnoea or a cancerous goitre were the three major predictive factors. [**]

However, when there are no abnormalities in the anaesthetic, medical or surgical history, the presenting disease process does not affect the head, neck or mediastinum and the patient does not ‘look’ difficult, then it is not possible to predict difficulty accurately.

Most attention has been on predicting difficult direct laryngoscopy using various specific or predictive tests (described above), combination of tests and scoring systems. All are imperfect and the reason is partly the low prevalence of difficult intubation. Test sensitivity indicates the ability of the test to label a difficult patient as difficult, test specificity the ability to label a normal patient as normal and the positive predictive value (PPV) is the proportion of patients found to be difficult out of all patients predicted by that test to be difficult. Table 39.2 shows values of test sensitivity, specificity and PPV for various tests. It can be seen that an individual test, such as Mallampati, has a low PPV indicating that most patients predicted to be difficult will, in fact, be normal. A study comparing the upper lip bite test with the Mallampati in 1425 patients concluded that ‘both tests are poor predictors as single screening tests’11. The more tests that are abnormal increases the likelihood that the patient will be difficult to intubate.

Another approach is to produce a score from consideration of various predictive tests, with appropriate weighting. In Wilson et al.’s risk sum,12 five aspects of examination are used – weight, head and neck movement, jaw movement, receding mandible and buck teeth. Each factor is allocated a score of 0, 1 or 2 depending on severity. Wilson’s group suggested that a total score of 2 or more would provide a sensitivity of 75 percent and specificity of 85 percent. These figures may appear to be good but one-quarter of difficult patients will be missed and there will be 1500 false alarms per 10,000 patients. A more recent French study4 produced a scoring system involving seven factors – previous difficult intubation, pathologies associated with difficult intubation, clinical symptoms of airway pathology, interincisor gap and mandibular luxation, thyromental distance, maximum range of head and neck movement and Mallampati. The maximum score is 48 and a score of 11 provided the best level of sensitivity and specificity.

The subject of prediction of difficulty is fraught with difficulties arising from studies with small numbers of patients, definitions, curious mathematics and inappropriate conclusions. The topic has been elegantly examined in an editorial which provides a review of the mathematics and an extensive list of references.13 A recent meta-analysis of bedside screening tests for predicting difficult intubation in apparently normal patients concludes that they have limited value.14 [**]

![Figure 39.5 Retropharyngeal abscess.](image)

Table 39.2 Test sensitivity, specificity and positive predictive value from the literature and reference 13.

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity %</th>
<th>Specificity %</th>
<th>PPV %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyromental</td>
<td>65–91</td>
<td>81–82</td>
<td>8–15</td>
</tr>
<tr>
<td>Mallampati</td>
<td>42–56</td>
<td>81–84</td>
<td>4–21</td>
</tr>
<tr>
<td>Wilson risk sum</td>
<td>42–55</td>
<td>86–92</td>
<td>6–9</td>
</tr>
<tr>
<td>Mouth opening</td>
<td>26–47</td>
<td>94–95</td>
<td>7–25</td>
</tr>
<tr>
<td>Neck movement</td>
<td>10–17</td>
<td>98</td>
<td>8–30</td>
</tr>
</tbody>
</table>

[**]
It must be remembered that the objective tests aim only to predict difficult direct laryngoscopy when the tongue has a normal compliance and the respiratory tract is normal. Fixation or restricted movement of the tongue was thought to be the direct cause of failed conventional intubation in a series of five patients\(^{15}\) and an abnormality, such as a vallecular cyst, may be symptomless and will not be predicted but may cause great problems with airway management.\(^{16}\) A number of patients who had been found to be unexpectedly difficult to intubate were reviewed and it was discovered that they all had lingual tonsillar hypertrophy.\(^{17}\)

Airway evaluation is an essential part of preoperative assessment. It may be rewarded by the detection of severe or obvious problems that necessitate a change from 'normal' management. When there are no obvious problems, evaluation is imperfect and safe airway management in all circumstances depends on the adoption of an airway strategy that is able to respond to unexpected difficulty with intubation or oxygenation.

**STRATEGY**

The recommendations of the ASA on management of the airway\(^{1,3}\) promoted the five-step linear model of evaluation of the airway, preparation for difficulty, strategy at intubation, strategy at extubation and follow-up. The ASA difficult airway algorithm presents an overall scheme of planning airway management and a recent version\(^{18}\) is shown in Figure 39.6. The algorithm indicates that airway difficulty may be predicted or unexpected and, in the unexpected limb, attention must first address oxygenation before employing alternative means of intubation. Strategy indicates a combination of plans, also known as plan A/plan B at both initial instrumentation of the airway (induction or intubation) and at the end of surgery (eduction or extubation). Each plan at the start of anaesthesia addresses ventilation of the patient, the abolition of laryngeal reflexes (if required), the airway device and method of insertion, and the abolition of patient distress. The default strategy when intubation is required is shown in Table 39.3. During intubation, there is no ventilation and the patient is oxygenated by intermittent face mask ventilation. Laryngeal reflexes are abolished by muscle relaxation, patient distress is overcome by general anaesthesia and intubation is by optimal direct laryngoscopy. The components of optimal direct laryngoscopy are optimal head and neck position, muscle relaxation, external laryngeal manipulation, laryngoscope blade length/design and use of the gum-elastic bougie. The bougie is the most useful

![ASA difficult airway algorithm](image-url)
ALTERNATIVE TECHNIQUES FOR TRACHEAL INTUBATION

When intubation by direct laryngoscopy fails, a number of alternative techniques should be considered.

Other laryngoscope blade design

The Macintosh curved blade design is the blade most commonly used by anaesthetists. However, it has a lower success rate than straight blade direct laryngoscopy by the right paraglossal approach. Recently, a British enthusiast, John Henderson, has designed his own straight blade and makes a good case for the reintroduction of the straight blade into mainstream anaesthesia.22 It is a similar technique to that employed by head and neck surgeons, and there seems to be little reason that anaesthetists and surgeons should view the larynx by differing techniques. Another blade, originally invented by McCoy, employs a lever to increase markedly the angulation of the tip (Figure 39.8). A number of direct laryngoscopy blades have been introduced over the years incorporating prisms or mirrors to try and provide an indirect view of the larynx but these have not become mainstream devices.

Flexible fibrescopes

Tracheal intubation using the flexible fibrescope was first described in 1967 by Peter Murphy,24 an anaesthetic senior registrar working at the National Hospital, Queen Square, London, and flexible intubating fibrescopes have been commercially available for over 20 years. Several textbooks25, 26 are concerned solely with the technique. A standard adult intubating fibrescope has a length of 60 cm and a nominal external diameter of 4 mm. Its narrow diameter allows it to pass through the nose or mouth, its flexibility allows it to conform to the anatomy of the patient, the working channel can be used to instil local anaesthesia, oxygen or to pass wires in the antero-
retrograde direction to aid intubation, the technique is visual and can be used to confirm correct positioning of the tube in the trachea. It is fairly easy to use anaesthetic breathing system connectors or attachments which allow concurrent ventilation of the patient during intubation, or specially adapted airways to make oral intubation easier. It is not surprising that such an instrument has become the safest and most successful technique of intubation. A Swiss study examines the results of 13,248 intubations from one hospital in which the fibrescope is used widely as the primary or back-up intubation technique. The failed intubation rate was 0.045 percent. Ovassapian gives figures of 98.4 percent success rate in over 2,000 fibreoptic intubations. The complication rate is extremely low.

Fibre-endoscopic skills appear in the core competencies for trainee anaesthetists and include visual inspection of the respiratory tract for diagnostic purposes and placement of double lumen tracheal tubes. The problems associated with the intubating fibrescope are that some skill is necessary, the device is expensive and repays careful handling, and disinfection requires chemical agents. There has been particular concern over the inability of cold sterilizing agents to destroy prions. The recommendation from the Department of Health is that a register should be maintained such that all patients treated with an individual fibrescope can be traced easily.

**Intubating laryngeal mask airway**

The intubating laryngeal mask was devised by Brain and introduced in 1999. The intubating laryngeal mask airway (ILMA) kit (Figure 39.10) differs from the classic laryngeal mask (LM) in several ways. The stem is a rigid highly curved metal tube with a handle, there is an epiglottic elevator bar, a ramp at the junction of the stem and bowl directs the tube appropriately and it is supplied with a special wire-spiral tracheal tube with novel bevel. The described technique of intubation in the anaesthetized, paralyzed patient is for the mask to be placed and the patient ventilated through it. Mask placement appears to be easy provided the mouth opening is more than 2 cm. The tracheal tube is inserted through the stem and advanced slowly without force. As the tip of the tube emerges from the stem, it lifts the epiglottic elevator bar and the route is now clear for the tube to be advanced into the trachea. This blind intubation has a success rate of 95 percent or so if two to three manipulations of mask position and tube advancement are allowed. A fibreoptic modification can be used which allows a visually guided technique and would seem to be preferable. In the largest
of difficult intubations published so far,\textsuperscript{29} the ILMA was used in 254 patients with a known difficult airway, including 50 patients with airway distortion due to tumour, surgery or radiotherapy. The successful intubation rate was 96.5 percent with a blind technique and 100 percent when used with the fibrescope.\textsuperscript{[**]} Another North American study\textsuperscript{30} compared intubation by the ILMA in anaesthetized patients with awake fibre-optic intubation in 38 patients with suspected difficult intubation and found them both to be 100 percent successful.

**Lighted stylets**

The technique of transillumination of the neck to guide oro- or nasotracheal intubation was described first in 1959. A lighted stylet\textsuperscript{31} uses the principle of transillumination and takes advantage of the anterior or superficial location of the trachea. A number of commercially available devices have been produced over the years and the most recent, the Trachlight, appears to be the most successful. The tracheal tube is loaded onto the stylet which has a distal bulb, and the stylet is shaped into a hockey-stick. The lighted stylet is introduced into the oropharynx from the side and brought into the midline. The tip of the lightwand is passed around the tongue and a bright, well-circumscribed circle of light seen externally at the level of the hyoid indicates that the tip lies in the vallecula. The tube is advanced into the trachea without resistance. In one large series of anticipated difficult intubation, successful Trachlight use by the inventor resulted in intubation in 99 percent patients with a mean time of 26 seconds.

**ROLE OF THE CLASSIC LM**

The classic LM is the most successful of all supraglottic airway devices for maintenance of the airway. In one study of over 11,000 patients, the incidence of failed placement was 1:600 patients. It is, of course, designed for maintenance of the airway in planned, elective surgery. It has the advantages, when compared with tracheal intubation, of easier placement, no requirement for muscle relaxation and is tolerated \textit{in situ} by the awakening patient. The major disadvantages are that it does not offer the same level of airway protection as a cuffed tracheal tube against gross gastric regurgitation and it does not traverse the larynx, so is no protection against airway occlusion by glottic or infraglottic pathology. It has, however, proved to be a very useful device in difficult airway management and appears in several places in airway algorithms (Table 39.4).

**Intubation via the LM**

In normal use, the LM should be seated in close proximity to the vocal cords and it is not surprising that it can provide a route for passage of a tracheal tube. There are five methods for this (Table 39.4). A size 6.0 mm will pass through the stem/connector of a size three or four LM and a size 7.0 mm tube will pass through the size five LM. Blind placement, in which the tube is lubricated and advanced blindly, has a success rate of only 50–90 percent and passing a bougie through the LM first has an even lower success rate. Techniques under vision have appreciably higher success rates and flexible fibreoptic techniques are particular useful. The fibrescope may be used to guide placement of a bougie into the trachea with intubation occurring over the bougie.

Fibreoptic-assisted techniques are useful because they are visually guided (Figure 39.11). The core technique is to insert the LM, load a 6.0 mm tube onto the fibrescope, pass the fibrescope into the trachea through the stem of the LM and slide the well-lubricated tube into the trachea. It is also possible to ventilate an anaesthetized patient through the LM whilst intubation is in progress. This introduces the concept of the laryngeal mask as a dedicated airway,$^{32}$ a device used for maintenance of

![Components of the intubating laryngeal mask airway.](image)

**Table 39.4** Role of the classic LM in difficult airway management.

<table>
<thead>
<tr>
<th>Role of the classic LM</th>
<th>Blind Bougie</th>
</tr>
</thead>
<tbody>
<tr>
<td>As the desired airway device</td>
<td>Fibreoptic-guided bougie</td>
</tr>
<tr>
<td>Instead of a tracheal tube</td>
<td>Fibreoptic</td>
</tr>
<tr>
<td>Rescue device in failed ventilation</td>
<td>Aintree catheter</td>
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<tr>
<td>Conduit during emergence</td>
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<tr>
<td>Conduit for fibre-endoscopy of the airway</td>
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<tr>
<td>Conduit for intubation:</td>
<td></td>
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$^{**}$ Another North American study compared intubation by the ILMA in anaesthetized patients with awake fibre-optic intubation in 38 patients with suspected difficult intubation and found them both to be 100 percent successful.

$^{31}$ A lighted stylet uses the principle of transillumination and takes advantage of the anterior or superficial location of the trachea.

$^{32}$ a device used for maintenance of the airway.
the airway whilst other airway interventions (e.g. intubation) are in progress. Development of this concept led to the design of the Aintree catheter, a hollow bougie which may be placed over the fibrescope and inserted through the LM into the trachea (Figure 39.12). Effectively, the technique places a hollow bougie under vision into the airway, over which a tracheal tube is railroaded.

**Failed ventilation and emergency cricothyrotomy**

Failed ventilation refers to the situation where a patient has been anaesthetized and muscle relaxants administered but it is not possible to provide positive pressure ventilation by use of the face mask and oral airway. A prepared sequence of steps should commence to provide rescue oxygenation as quickly as possible. Bag/mask ventilation in which two hands are used to try to maintain airway patency and another hand squeezes the anaesthetic reservoir bag should be followed by insertion of a classic LM. This may prove life-saving and must always be considered. If oxygenation cannot be achieved by face mask or LM, it may be worthwhile attempting intubation by direct laryngoscopy. This must be a brief attempt only and must not delay oxygenation by the next step. Airway deaths, unfortunately, often involve prolonged fruitless attempts to intubate when oxygenation is the immediate necessity. When the anaesthetized patient cannot be oxygenated by face mask or LM, and tracheal intubation is not possible, emergency oxygenation should be attempted directly into the respiratory tract below the level of the vocal cords. Anaesthetists generally use the cricothyroid membrane (CTM) which has a number of desirable properties:

- superficial;
- easy landmarks to locate;
- present in most patients;
- rarely calcifies;
- relatively avascular;
- wide enough to accept 6.0 mm tube;
- inferior to vocal cords;
- cricoid ring holds airway open;
- posterior lamina protects back wall.

There are three types of cricothyrotomy as detailed in the following sections.

**Needle or small cannula cricothyrotomy**

A narrow-calibre rigid needle or flexible cannula is inserted through the CTM in a caudad direction. In adults, an appropriate size is 14 G with an internal diameter of 2 mm (Figure 39.13). The resistance to flow through such a calibre is high and this has implications for inspiration and expiration; in inspiration, adequate gas flows cannot be obtained by the pressures generated within a standard anaesthetic breathing system and exhalation of 500 mL takes >30 seconds. Inspiratory gas flows of 500 mL/s require oxygen at a pressure of 2–4 bar supplied by a Sanders injector (Figure 39.14). The Sanders injector attaches to the 4 bar (400 kPa, 4 atmospheres) oxygen pipeline and has a hand-operated lever to control gas flow during inspiration. Exhalation occurs through the upper airway and particular attention must be taken to ensure that this happens, otherwise airway pressures rise and pulmonary barotrauma develops. A needle cricothyrotomy is a temporary measure and consideration must be given to creation of a tracheostomy in relevant circumstances. It is possible for ventilation via needle cricothyrotomy to be used in the planned elective or urgent case. Figure 39.15 shows a patient whose partial denture had fallen into the pharynx in such a position that the larynx was obscured. The cricothyrotomy needle was placed in the awake patient and its correct position in the trachea confirmed by aspiration of free air and attachment of the capnograph to show an appropriate trace. Following intravenous anaesthesia and
muscle relaxation, the Sanders technique of intermittent application of high pressure oxygen provided adequate oxygenation and ventilation. Exhalation through the upper airway was unobstructed.

**Large cannula cricothyrotomy**

A purpose-built cannula with an internal diameter of >4 mm allows adequate inspiratory gas flows with the pressures generated by the standard breathing system and exhalation of 500 mL takes approximately 5–6 seconds. This is an advantage because there is no requirement for high pressure oxygen. It is easy to attach the capnograph to the circuit for confirmation of correct positioning within the trachea, and to suction the respiratory tract. Exhalation occurs through the cannula, even in the presence of complete upper airway obstruction. The cannula may be a cannula-over-needle or a Seldinger-type dilatational device. Cannula-over-needle devices place an uncuffed tube whereas the Melker Seldinger device allows positioning of a 6.0 mm cuffed tube. There are advantages in placing a cuffed tube in allowing controlled positive pressure ventilation and protecting the airway.

**Surgical cricothyrotomy**

The technique is to make a 3 cm midline incision in the skin followed by a horizontal stab incision in the inferior part of the cricothyroid membrane. The incision is spread horizontally and vertically and a 6 mm tube is inserted. The complication rate was 40 percent in one series of 38 emergency surgical cricothyrotomies. Misplacement and bleeding requiring ligation of vessels were the most common problem. A more rapid four-step technique has been described in which a single horizontal incision is made through the skin and cricothyroid membrane together. In a cadaver study, emergency physicians compared the standard and rapid technique. The rapid technique was faster than the standard 43 versus 134 seconds, but the complication rate was higher. The horizontal incision through the skin may cause more haemorrhage. A cricothyrotomy tube should not be left in place for more than a few days and conversion to tracheostomy prevents the complications of dysphonia and subglottic stenosis.

**OBSTRUCTED AIRWAY**

The obstructed airway is one in which the primary symptoms or signs are due to narrowing or distortion of the airway. There are two broad clinical presentations. In acute obstruction (Figure 39.16), a previously normal person develops problems over a matter of minutes or hours. The aetiology is usually one of inhaled foreign body or abnormal fluid accumulation, such as blood, pus or oedema. Typical clinical scenarios are infections in the head and neck, postoperative haematoma, and airway swelling secondary to anaphylaxis or angiotensin-converting enzyme inhibitors. The rapidity of onset produces prominent signs of difficulty with breathing and the patients may present in extremis. Imaging of the airway by x-ray, CT or MR scan is often inappropriate because
the patient may be unable to adopt the necessary position to complete the procedure and the radiology suite is not an appropriate location for a patient with a deteriorating airway. The management of acute obstruction includes 100 percent oxygen by face mask, trial of administration of heliox, nebulized adrenaline (epinephrine) if oedema is prominent, drainage of pus, tracheal intubation or emergency cricothyrotomy or tracheostomy. Heliox is a combination of oxygen 21 percent and helium 79 percent and is three times less dense than air because of the low atomic weight of helium (4) compared with nitrogen (14). In airway obstruction, turbulent gas flow is inversely proportional to the square root of density and the use of heliox improves gas flow in turbulent conditions and also promotes laminar flow. It is suggested also that carbon dioxide molecules diffuse four to five times faster through heliox than an equivalent oxygen–nitrogen mixture and this may enhance carbon dioxide excretion in the airway.

In chronic obstruction, the airway pathology has developed over a period of weeks or months and is usually due to growth of tissue or to scarring. The slow onset allows development of enlarged intercostal muscle mass and patients can tolerate a very significantly narrowed airway without symptoms. Generally, a patient will not be dyspnoeic at rest until the airway is narrowed to <5 mm diameter, although they are likely to be short of breath on exercise. The slower time course of obstruction allows complete imaging of the airway and controlled intervention. Appropriate imaging in the stable, chronic condition is through flexible nasendoscopy and CT or MR imaging of the entire airway. Flow-volume loops may be helpful in detecting that a patient’s problem is large airway narrowing and not truly pulmonary, or assessing the degree of tracheal narrowing before planning surgery.

Evaluation of the obstructed airway seeks to define the degree of obstruction, likely site, rapidity of onset and likely time course of deterioration by history, examination and special investigations. The history from the relative or patient usually indicates whether this is acute, chronic or acute-on-chronic. Specific symptoms/signs in airway obstruction are degree of difficulty with breathing, stridor (noisy breathing) and phase of respiration of any stridor. Stridor indicates that the airway is narrowed to <50 percent normal diameter, but this degree of airway narrowing is not always accompanied by stridor. Expiratory stridor indicates an infraglottic problem and inspiratory stridor a supraglottic aetiology. There may be a positional aspect to the difficulty with breathing and patients may be more comfortable in the sitting or lateral position. Voice change and difficulty with swallowing may indicate the site or extent of disease, and pyrexia or sepsis indicates an infective component. Unilateral reduction in breath sounds in the chest indicate specific bronchial obstruction. With progressive obstruction, signs of ineffective ventilation and poor gas exchange are present. These include agitation, anxiety, confusion, restlessness and depressed level of consciousness. Increased work of breathing is indicated by a high respiratory rate, use of accessory muscles of respiration, flaring nostrils, sweating and tachycardia. Oximetry is not a good monitor of work of breathing and normal oxygen saturation does not indicate that all is well. In severe acute obstruction with untrained respiratory muscles, exhaustion occurs relatively quickly with a resulting decrease in effective minute ventilation, hypoxaemia, bradycardia and death.

Management strategy in the obstructed airway

The Confidential Enquiry into Perioperative Deaths (CEPOD) report examined 30 patients who had died within 30 days of surgery for management of lesions in the upper airway or who presented with stridor. In most cases death was due to the underlying disease process but in some cases difficulties with maintenance of the airway led to death in the operating theatre or recovery unit. Brief case scenarios are given in the report and one describes a 76-year-old patient with fixed cervical spine flexion (due to rheumatoid arthritis) and a retrosternal goitre. After induction of anaesthesia with thiopentone and muscle relaxation with suxamethonium,
The patient proved impossible to intubate and mask ventilate adequately. An emergency tracheostomy proved difficult and cardiac arrest occurred in theatre.

The surgical and anaesthetic assessors made several good recommendations. The patients should be seen by the consultant surgeon and anaesthetist who consider carefully the plan for securing the airway. Imaging of the airway should be obtained, if possible, to allow delineation of whether the airway is narrowed at supraglottic, glottic or infraglottic level. Airway strategy should include a primary and back-up plan with coherence between the individual plans. If a long-acting muscle relaxant is used in plan A, plan B cannot rely on a patient ‘waking-up’. If a surgical tracheostomy is the back-up plan, anaesthesia should start in the operating theatre with the equipment, surgeon and theatre team immediately ready – it is foolish to start anaesthesia in the anaesthetic room and scramble into theatre when plan A fails. [*]

There has been much discussion in the anaesthetic literature about provision of anaesthesia in the presence of the abnormal airway but general agreement that classification according to the site of obstruction is helpful. Currently, the terms used by anaesthetists are not as precise as the ones used by surgeons to localize tumours.

**SUPRAGLOTTIC** OBSTRUCTION

In ‘supraglottic’ obstruction the obstruction is above or superior to the glottis and the glottic aperture is of normal dimensions. An example would be a base of tongue tumour (Figure 39.17), although clearly this is not truly a supraglottic structure in disease terminology. Direct laryngoscopy is likely to prove difficult and may cause bleeding if the blade contacts the tumour. It may also prove difficult to ventilate by face mask following induction of general anaesthesia. In this circumstance it is helpful to retain spontaneous respiration and to use an alternative means of intubation. Awake fibreoptic intubation (Figure 39.18) by the nasal or oral route has much to recommend it and was used successfully in a series of 26 adult patients with deep neck infections including classical Ludwig’s angina. [*]**

Awake intubation is a misnomer because it is very difficult to intubate a truly awake patient. The more correct term is tracheal intubation under topical anaesthesia with conscious sedation. It has a very good record of safety in airway management because the patient maintains their own airway and continues with spontaneous respiration until the airway is secure. It is possible for the patient to adopt a change in position, such as sitting up, and to aid intubation by protruding their tongue, vocalizing or taking deep breaths. There are a number of intubation techniques in an awake patient, such as oral direct laryngoscopy, blind intubation through the nose, through the classic or intubating laryngeal masks or a retrograde wire technique. Awake fibreoptic intubation appears to be the best technique, combining awake intubation with a visually guided method of both inspecting and intubating the airway, applying local anaesthesia to the airway and confirming correct positioning of the tube within the trachea. Fibreoptic intubation is generally easier in the awake rather than anaesthetized, paralysed patient because airway patency is maintained, the airway opens and closes with respiration and the flow of gas indicates the route to the larynx.

There are a number of specific practical steps and attention to detail is required. Premedication may be employed if there is no airway embarrassment, but should be avoided if there are symptoms or signs of airway obstruction. An antisialogogue is important and absence of secretions allows earlier and more profound topical anaesthesia, and easier fibre-endoscopy. Preoperative
intramuscular atropine 0.6 mg, hyoscine 0.4 mg or glycopyrrolate 0.4 mg are suitable but it is common to administer glycopyrrolate 0.2–0.4 mg intravenously as soon as the patient arrives in the operating room.

Sedation aims to provide a comfortable patient who maintains spontaneous respiration, airway patency and verbal contact. Small incremental doses of a benzodiazepine and opioid are administered, taking care not to produce oversedation. Typical total doses are midazolam 1–5 mg and fentanyl 25–100 µg. Both drugs have a peak onset of five minutes and a specific antagonist (flumazenil and naloxone, respectively). Benzodiazepines cause relaxation of genioglossus and destabilization of the airway and opioids are associated with central respiratory depression so neither drug is benign. However, appropriate doses produce a compliant patient who is not unduly upset by airway topicalization or instrumentation, and is usually amnesic. Propofol, an anaesthetic agent, provides sedation at subhypnotic concentrations and is particularly useful when given by target-controlled infusion. Target controlled infusion (TCI) devices are sophisticated syringe pumps which incorporate a pharmacokinetic model of the relevant drug. The operator enters the age and weight of the patient and the desired blood level. The TCI pump calculates and delivers the appropriate bolus dose to reach the required blood level and the subsequent infusion required to maintain it. Appropriate starting blood levels for propofol are 0.5–1.0 µg/mL. Remifentanil, an ultrashort-acting opioid, may also be used by TCI and is gaining a reputation as a useful opioid for awake intubation. If the nasal route is chosen for intubation, a topical vasoconstrictor should be applied. This may be xylometazoline or ephedrine 0.5 percent drops or cocaine (3 mL 5 percent), which produces both vasoconstriction and topical anaesthesia.

Topical anaesthesia may be provided by:

- nebulization;
- translaryngeal administration;
- specific nerve blocks;
- transendoscopic administration.

Nebulization sounds attractive but use of the technology which provides particles for alveolar deposition of drug (e.g. salbutamol nebulizer), may lead to disappointing results partly because the particles are too small but also because a large amount of the drug escapes to the atmosphere. High-drug concentrations may be effective and nebulized lignocaine 10 percent in a dose of 6 mg/kg has been described as effective. A useful variant is the production of a larger droplet size produced during inspiration. This manual spray-and-inhalne technique employs a 22 g Venflon attached to a constant oxygen flowrate of 1–2 L/min. Small increments of lignocaine 4 percent are injected through the port of the cannula and coordinated with inspiration. One spray-and-inhalne regime is to use 3 mL lignocaine 4 percent with ephedrine 15 mg to the nose, wait three minutes and apply the second 3 mL lignocaine 4 percent, asking the patient to inspire deeply and slowly through the nose. The droplets are inhaled and deposited onto the larynx and trachea. After a three minute wait, a further 3 mL lignocaine 4 percent is nebulized during slow forced inspiration. Maximum lignocaine dosage should be 9 mg/kg.

Translaryngeal administration has a long history of safe use. A study reviewing 17,500 administrations reported only six noteworthy complications. A 22 G cannula or needle is passed through the cricothyroid membrane or trachea and 3–4 mL lignocaine 4 percent is injected preferably at end-expiration. The injection provokes a short period of intense coughing which distributes the drug to the glottis and above. The experimental addition of methylene blue to the local anaesthetic shows staining of the superior aspect of the vocal cords in 95 percent of patients.

Appropriate specific nerve blocks are of the superior laryngeal and glossopharyngeal nerves. The internal branch of the superior laryngeal nerve supplies sensation to the under surface of the epiglottis and the superior surface of the vocal cords. It may be blocked on each side as it traverses the thyrohyoid membrane. Extension of the head and neck aids identification of the hyoid and thyroid cartilages. A 22 G needle is placed inferiorly to the greater horn of the hyoid, passed into the membrane and 2 mL lignocaine 2 percent is injected. The glossopharyngeal nerve supplies sensation to the posterior third of the tongue, superior part of the epiglottis, lateral pharyngeal wall and inferior surface of the soft palate. The nerve may be blocked behind the anterior pillar of the tonsillar fossa. With full mouth opening the tongue is grasped and pulled to the contralateral side. A 20 G spinal needle is inserted to a depth of 5 mm into the base of the anterior tonsillar pillar at the level of the reflection onto the tongue, and 2 mL lignocaine 2 percent injected. Bilateral glossopharyngeal nerve blocks will abolish the gag reflex and allow greater manipulation in the oropharynx or direct laryngoscopy, perhaps when placing a large double lumen tube. These specific nerve blocks are not performed routinely.

Transendoscopic administration of lignocaine 4 percent through the working channel of the intubating fibrescope is an extremely effective means of applying local anaesthetic to the airway under vision. This spray-as-you-go technique is highly favoured and noninvasive. The intubating fibrescopes have connectors for injection but an easier alternative is to place an epidural catheter, cut to produce one terminal hole, substantially into the working channel (Figure 39.19). Aliquots of lignocaine 4 percent to a maximum dose of 9 mg/kg are administered.

It is helpful for the fibrescope to be attached to a CCTV system, particularly for training. An appropriate size tracheal tube is loaded onto the fibrescope and the scope is introduced under vision into the mouth or more patent nostril. The fibrescope is advanced without
touching the mucosa until the vocal cords are seen. Additional local anaesthetic may be applied before the fibrescope is advanced to the carina. The tube is advanced or roadrolled over the fibrescope. This may be difficult because the bevel impinges on the larynx. Use of a small diameter tube and rotation of the tube minimize this problem.

Awake fibreoptic intubation may be difficult when the airway anatomy is abnormal and when there is blood or secretions in the airway. An illustrative case scenario indicates some of the pitfalls in management. An adult patient underwent removal of a fishbone impacted in the lower pharynx/upper oesophagus. Three days later the patient was pyrexial, with a sore throat, unable to swallow and with limited mouth opening. A lateral x-ray of the neck showed a retropharyngeal abscess. The patient was seen by two anaesthetic trainees who did not inform the consultant on call. They decided on an awake fibreoptic intubation but administered too much sedation. In a deteriorating situation with a semirepose patient they attempted nasal fibreoptic orotracheal intubation (FOI) with the patient supine. They were unsuccessful and were moved aside by the consultant surgeon who managed to intubate the patient fibreoptically with the patient sitting, leaning forward on the edge of the operating table. Mistakes made here include failure to appreciate the seriousness of the condition and to inform a consultant, failure to realize that awake nasal FOI in the supine position would be difficult in the presence of retropharyngeal swelling and failure to realize that airway patency would be compromised by any sedation.

**PERIGLOTTIC/GLOTTIC OBSTRUCTION**

In these situations it may be difficult to visualize the vocal cords by direct laryngoscopy and the glottic aperture may be significantly narrowed or distorted. Much lively discussion is evident over the correct anaesthetic technique. When awake fibreoptic intubation is used, it allows visualization of the airway but becomes less useful in the patient with stridor due to glottic narrowing. The fibrescope has little rigidity to ‘push’ through a narrow hole and attempts to do this may precipitate bleeding and oedema. If the scope is passed through a small hole, the airway is completely obstructed for a short time and patients feel uncomfortable at this stage. There have been a few reports of destabilization of the airway by applanaesthetic agent to the airway and this is a reminder of the need to work at all times in the correct environment for immediate activation of the preformulated back-up plan. Awake fibreoptic intubation is, therefore, a technique which should always be considered but may not be suitable. It is not appropriate when adequate operator skill is not present, in children and uncooperative adults and in the opinion of some anaesthetists when stridor is present.

Mason and Fielder argue that the correct anaesthetic technique in the presence of stridor due to periglottic/glottic pathology is inhalational induction of general anaesthesia. This permits a gradual onset of anaesthesia and maintains spontaneous respiration, even at a depth of anaesthesia appropriate for direct laryngoscopy and intubation. The maintenance of spontaneous respiration is viewed as highly desirable with supraglottic airway obstruction. A typical case scenario would be a child with epiglottitis and, in a survey of college tutors in the UK, 98 percent of anaesthetists would choose this form of anaesthesia. The face mask is applied to the patient who is in the most comfortable position (sitting if necessary) and 100 percent oxygen administered for a few minutes. The volatile agent is administered in increasing concentrations until a surgical level of anaesthesia is obtained. The agent commonly used initially is either halothane or sevoflurane and both drugs are nonirritant so do not provoke coughing. The speed of onset of anaesthesia is inversely proportional to the blood–gas solubility and is therefore faster with sevoflurane (0.6) than halothane (2.4). However, it is more difficult to establish sufficient depth of anaesthesia to instrument the airway with sevoflurane and it has a more rapid offset than halothane. Halothane may be associated with increased cardiac rhythm irritability and is now difficult to obtain in the UK. It is usual, therefore, to start with sevoflurane but change over to isoflurane which does permit adequate levels of anaesthesia.

It is not an easy anaesthetic to administer in the presence of stridor and requires a sanguine anaesthetist. There may be periods of increasing obstruction due to glottic irritability or change in position. Generally, there should be no change in the position of the anaesthetist’s hands or the face mask and no attempt in light planes of anaesthesia to provide positive pressure ventilation. Insertion of an oral airway is risky but there may be benefit in a nasopharyngeal airway, although it is perhaps useful to have applied a vasoconstrictor to the nasal mucosa first. Glottic irritability is confined to light planes of anaesthesia and should resolve, although induction
may take much longer than normal because of the reduced alveolar ventilation. When an adequate depth of anaesthesia is reached, which may take 20 minutes, direct laryngoscopy is undertaken. The view may be quite abnormal and it may be necessary to press on the chest and observe the egress of bubbles to detect the glottis. A small tube will be needed and the use of a bougie should be considered. If intubation is not possible, the face mask is reapplied and a tracheostomy undertaken. Plan B must be formulated and ready so that anaesthesia is induced in the operating theatre with the surgeon scrubbed and ready to undertake tracheostomy.

It is apparent that the safety of any approach is the combination of plans and the close cooperative working of the surgeon, anaesthetist and theatre team. In the common scenario of a known obstructing glottic tumour which requires initial histology and debulking, it is possible to construct a primary plan of (in the operating theatre) preoxygenation, followed by intravenous induction and rapid muscle relaxation. Direct laryngoscopy using a bougie and size 5.0 mm micro-laryngeal tube is attempted. If it is unsuccessful, the surgeon is in the best situation to undertake tracheostomy – the patient is as well oxygenated as possible, unconscious and remains still. This technique is logical and popular but appears ‘heretical’ since it abolishes spontaneous respiration. However, it illustrates that safety lies in the combination of plans rather than any particular plan A, that the site of obstruction requires plans which are specific for that level of obstruction and the safety which arises from the close working of experienced surgeon and anaesthetist.

There is an increasing evidence-base to the practice of planned prior placement of a transtracheal ventilation catheter under local anaesthesia and using this as a route for oxygenation and ventilation during intubation attempts under general anaesthesia. The technique was used in 11 patients over 22 months in one institution with great success.44 [**]

TRACHEOSTOMY UNDER LOCAL ANAESTHESIA

This should be considered in any patient with an obstructed airway. It is particularly appropriate as the primary plan when the disease process is a large friable mass or abscess in the supraglottis or glottis and intubation attempts may destabilize or compromise the airway. There are differences between countries and between surgeon–anaesthetist pairs as to when the patient undergoes traditional intubation in the awake or anaesthetized state or awake tracheostomy. Elements within the decision making are the availability of a skilled fibre-endoscopist, the ability of the patient to cooperate with the procedure and adopt a suitable position, the pretracheal anatomy and the likely time for resolution of the disease process. It may be a very difficult procedure in patients with short stocky necks, a previous tracheostomy or post-radiotherapy with respiratory distress.

Tracheostomy under local anaesthesia is undertaken in the operating theatre with the patient breathing oxygen or heliox, monitored by noninvasive blood pressure, ECG and pulse oximetry with intravenous access. A semisitting position with a roll under the shoulders and neck extension is ideal. Generally, reassurance is given to the patient but intravenous sedation is not required and should be used cautiously. Restlessness during the procedure may be due to hypoxia, hypercarbia or an inability to breathe in that position. Sedation may destabilize the airway leading to sudden hypoxia and loss of consciousness. The anaesthetist must be prepared for the back-up plan if the patient deteriorates. Placement of a cricothyrotomy needle at the outset may be useful when it is known that the pathology is supraglottic. The cricothyrotomy needle does not interfere with a surgical tracheostomy and can be used to provide oxygenation. If the patient becomes so restless that the surgeon is unable to operate, consideration should be given to providing general anaesthesia and oxygenation through the needle.

Another option in the distressed patient is to provide sedation/anaesthesia by addition of a volatile anaesthetic agent, such as sevoflurane, to the breathing system with 100 percent oxygen. At best, the airway proves to be adequate enough to allow a surgical plane of anaesthesia to be reached and the tracheostomy is undertaken in a relatively unhurried fashion on 100 percent oxygen/sevoflurane by face mask. At worst, the airway deteriorates with the onset of sedation/anaesthesia but the patient stops moving and a rapid emergency tracheostomy can be undertaken. In a rapid tracheostomy, the surgeon enters the airway with one or two incisions and a small cuffed microlaryngeal or armoured tube size 5.0–6.0 mm is inserted. Once the patient has been stabilized, a more measured exploration of the neck and fashioning of a formal tracheostomy may be undertaken.

It is important to verify that the tube is within the trachea before ventilation starts otherwise gas may be forced into the mediastinal tissues. Signs of correct placement when undertaking a tracheostomy under local anaesthesia (with the patient breathing spontaneously) are firstly regular respiratory movement of the reservoir bag of the anaesthetic breathing system connected to the tracheostomy tube, and the presence of six successive breath-related carbon dioxide traces on the capnograph. If no carbon dioxide is detected in the breathing system, inflation of the cuff of the tracheal tube or tracheostomy and connection of the capnograph to the breathing system should be checked first. If both are correct, failure to detect carbon dioxide indicates that the tube is not in the airway. When an emergency tracheostomy is undertaken in an apnoeic patient, the confirmatory signs of anaesthetic bag movement and capnography can be obtained only by applying a number of positive pressure breaths. If the tube is not within the trachea, these
positive pressure breaths into the mediastinum may prove deleterious. An alternative confirmatory device in these circumstances, although not widely used, is the oesophageal detector device. The principle is simple and takes advantage of the structural differences between the oesophagus and trachea. In the original version described by Wee in 1988, an empty 60 mL syringe is attached to the 15 mm connector of the inserted tracheal tube and aspiration attempted. Aspiration of air is not possible if the tube is in the oesophagus because the mucosa is ‘sucked’ over the end of the tube, whereas the more rigid cartilaginous structure of the trachea allows free aspiration of air. The syringe can be replaced by a self-inflating bulb with a volume of approximately 75 mL and in this version the bulb is squeezed flat before being attached to the inserted tube. If the bulb reinflates immediately, the tube is in the trachea and if the bulb does not reinflate the tube is in a false passage or the oesophagus.

SUBGLOTTIC AND MIDTRACHEAL OBSTRUCTION

Imaging is particularly useful in delineating the length of narrowing, the diameter of the airway at its narrowest and that sufficient distance is present inferiorly to the obstruction to permit the cuff of a tracheal tube to be positioned above the carina. The obstruction may arise from external pressure, such as a retrosternal goitre or other mediastinal mass, from a mass arising from the trachea, from an inflammatory condition such as Wegener’s granulomatosis, from previous surgery or from damage due to prolonged intubation. The type of narrowing may range from a short subglottic stenosis due to previous prolonged intubation to a narrowing of several centimetres in the midtrachea due to tumour. In the presence of stridor, the principles of management vary according to whether it can be bypassed by tracheostomy. This will be true for subglottic disease but the CEPOD assessors noted that in two patients it had been difficult to bypass a mid/lower tracheal lesion with a standard length tracheostomy tube. Awake fibreoptic intubation has a role in management of trachea narrowing, allowing inspection of the airway and confirmation that the tip of the tracheal tube has passed beyond the obstruction. Rigid bronchoscopy is an extremely effective means of managing these patients.

LOW TRACHEAL OBSTRUCTION

Narrowing of the lower trachea or carina presents great difficulty. The anaesthetic literature contains case reports of failed airway maintenance leading to death. This characteristically occurs after induction of general anaesthesia or muscle relaxation when, presumably due to loss of muscle tone, airway patency is lost. Tracheal intubation may not provide an adequate airway because the obstruction is beyond the tip of the tube. Occasionally, the presence of carinal obstruction is not known and anaesthetic induction, intubation or indeed extubation may result in unexpected disaster. When imaging has provided good preoperative localization of obstruction, a number of options may be used. Rigid bronchoscopy is invaluable and will often provide a route for ventilation (Figure 39.20). The rigid bronchoscope may also act as a guide to therapy, such as lasering of a tumour or introduction of a tracheobronchial stent. Surgical resection of carinal lesions requires specialist anaesthetic techniques including jet ventilation and undertaking surgery during cardiopulmonary bypass.

EXTUBATION AND RECOVERY

At the end of surgery a decision is made as to where and when the airway device should be removed. There is little problem with removal of a laryngeal mask. This is usually tolerated well by a patient until they are awake. Tracheal intubation is common in head and neck surgery due to

Figure 39.20 Rigid bronchoscopy used for ventilation and conduit for tracheal stent.
the constraints of providing clear operative fields for the surgeon and maintaining a secure airway to the distal trachea. Extubation requires as much thought, and gives rise to as much difficulty, as intubation. Transient difficulties with oxygen saturations are common due to coughing, breath-holding and laryngospasm, particularly in children. Extubation problems may arise in those patients who were difficult to intubate and those who were not difficult to intubate but in whom surgery has affected the airway.

Default strategy at extubation when no difficulty is expected is for the anaesthetist to remove any pharyngeal packs, suction the pharynx under direct vision, administer 100 percent oxygen, antagonize residual neuromuscular blockade and consider whether to remove the tube in the anaesthetized or awake state. After extubation, 100 percent oxygen is administered by face mask and the patient observed by the anaesthetist until it is clear that the patient is safe to go to the post-anesthetic care unit (Recovery).

In the patient with a normal airway who was difficult to intubate, it is prudent to make certain that oxygen stores are maximal and to extubate in the awake state. Lung oxygen stores can be considered maximal when the end-tidal (i.e. alveolar) oxygen is 91 percent. This may take at least five minutes of breathing 100 percent oxygen or longer if nitrous oxide has been used. Awake extubation refers to removal of the tracheal tube when the person has opened their eyes and is able to obey commands. An additional option is to assess the leak around the tube before removal. This may be carried out by applying positive pressure to the tube, deflating the cuff and listening for egress of gas around the tube, or alternatively occluding the tube in spontaneous respiration and making certain that inspiration can occur around the tube. Failure of a leak test indicates that the tube is a very tight fit within the airway and an inadequate air passage may be left after extubation.

In the patient with an abnormal airway, either present preoperatively or due to surgery, consideration should be given to keeping the tracheal tube in situ for 24–48 hours until any airway oedema subsides. The patient should be nursed in a high-dependency unit with an appropriate level of sedation to avoid inadvertent removal of the tube. In some circumstances it is appropriate to perform a tracheostomy to provide a secure airway in the first few postoperative days.

Extubation of the high-risk airway requires a strategy. Awake extubation after maximal oxygenation in the presence of an anaesthetist in a well-equipped environment may be a good plan A, but what happens if it fails? The situation rapidly becomes critical with a struggling, hypoxic patient possibly with blood in the oropharynx. One possibility is to extubate over a thin bougie and to leave the bougie in the airway for a period until it is certain that the patient is coping satisfactorily. The bougie acts as a guide if reintubation is required and, if it is hollow, may be used for emergency oxygenation.

Problems may arise in the Recovery unit or postoperatively on the ward. Of most concern is postoperative bleeding following carotid endarterectomy or removal of a parapharyngeal mass. The physical presence of a mass of blood may compress the airway itself but also induces mucosal oedema, perhaps by impairment of lymphatic drainage. The deterioration of the airway may be very dramatic and necessitate emergency cricothyrotomy or tracheostomy as part of resuscitation. In a dire situation it is always worth fitting an LM. It is helpful to open the wound and evacuate the blood clot and this may provide temporary improvement. The patient is returned to theatre for surgical exploration. Intubation should take place with the patient breathing spontaneously, if possible. This may be by awake intubation or with inhalational anaesthesia. Blood in the pharynx may impair the view and the first response is to try suctioning. An LM may cover the larynx and provide some respite before being used as a conduit for intubation. Emergency tracheostomy may be required (Figure 39.21). In this patient, drainage of a peritonsillar abscess had been undertaken with intubation by awake fibreoptic intubation. The patient had been extubated and returned to Recovery. Approximately 45 minutes later, the patient developed severe breathing difficulties and was returned immediately to the operating theatre. Awake intubation was not possible due to soiling of the airway, the patient was too restless to adopt a position suitable for formal tracheostomy and, in a deteriorating situation, the surgeon managed to carry out a rapid emergency tracheostomy.

**FOLLOW-UP**

Following difficulties with airway management, a certain scheme should be followed. An account of the problem and management should be written in the anaesthetic record and in the hospital notes. The patient needs to be reviewed clinically to detect and treat any morbidity, an explanation is required for the patient with details of the problem encountered and management, and a written
account should be sent to the patient with a copy to their general practitioner. If the problem with airway management is likely to be recurrent with subsequent anaesthetics, consideration should be given to the patient registering with Medic Alert and wearing a bracelet or to registering the patient with the difficult airway database supported by the Difficult Airway Society. [*] Immediate morbidity or mortality from difficult airway management arise from the effects of severe hypoxia, hypercarbia or cardiovascular responses, from failure to adequately protect the airway leading to aspiration and from physical trauma to the airway during attempts at intubation or resuscitation. Airway damage may occur even when airway management has not been notably difficult. Valuable information can be obtained from detailed analysis of the medical information contained in insurance reports, once claims for negligence have been settled or closed. In an analysis of such closed claims in North America, 6 percent of 4460 claims were for airway injury. The most frequent sites of injury were the larynx (33 percent), pharynx (19 percent) and oesophagus (18 percent). Approximately 20 percent of laryngeal injuries were associated with difficult intubation and included granuloma formation, arytenoid dislocation and hoarseness. Injuries to the pharynx and oesophagus had a much stronger association with difficult airway management. Half of all pharyngeal injuries and 68 percent of pharyngeal perforations were associated with difficult intubation.

There were five deaths in the pharyngeal injury claims and all involved perforation and the development of mediastinitis. The oesophageal injuries involved a significantly greater proportion of females and patients older than 60 years than the other sites and oesophageal perforation involved difficult intubation in 67 percent of claims. Oesophageal injuries were the most severe and were associated with a poor outcome with 19 percent mortality. Pharyngo-oesophageal perforation is a serious condition (overall mortality 25 percent) and risk factors include difficult intubation, emergency intubation and intubation by inexperienced personnel. Perforation may also be caused by passage of a nasogastric tube. The triad of surgical emphysema, chest pain and pyrexia should be sought and treatment with antibiotics, limitation of oral intake and surgical review initiated as soon as possible. In the closed claims study, surgical emphysema was only evident in 56 percent of patients and the diagnosis was sometimes delayed. It is suggested that treatment within 24 hours improves outcome. [*]

### Key Points

- The difficult airway is an important feature in head and neck surgery.
- Difficult intubation and difficult mask ventilation are different entities.

### Best Clinical Practice

- All patients should undergo airway evaluation as part of preoperative assessment.
- Strategy must cover unexpected failed intubation and failed ventilation.
- The LM is a versatile airway device and should always be available.
- Decisions about management of the obstructed airway are made by senior anaesthetists and surgeons.
- Awake fibreoptic intubation and tracheostomy under local anaesthesia should be considered in the obstructed airway.
- Maintenance of spontaneous respiration is recommended when general anaesthesia is employed in the presence of upper airway obstruction.
- Consider placement of a transtracheal ventilation catheter prior to inducing general anaesthesia in the difficult upper airway.
- Always confirm correct placement of the tube in the trachea.
- A strategy is required for extubation.
- Follow-up is important to detect and treat morbidity caused by airway management.

### Deficiencies in Current Knowledge and Areas for Future Research

- Unified surgical and anaesthetic terms describing the location of disease pathology in the airway.
- Randomized comparative studies of anaesthetic techniques in management of the obstructed airway.
- National collection of serious adverse incidents resulting from airway management in head and neck disease.
REFERENCES

Chapter 39 Recognition and management of the difficult airway