Elaine Bromiley
[died in the UK in March 2005 at the age of 37]

Brought about a re-look at the role of human factors (HF) in critical incidents in medical practice in the UK.
Libby Zion  
[died in the US in October 1984 at the age of 18]

Admitted to A+E with agitation, confusion and muscle twitching. Given Demerol despite a history of depression for which she took Nardil (phenelzine). Became restless, tied down. Died from high fever within 8 hours from admission. Later there were claims that she also took Cocaine.
Throughout his crusade, Sidney Zion's anger was paramount. Indeed, it is quite possible that without this rage, he might not have accomplished what he did. Zion was "aggressive, narcissistic, self-indulgent, pushy, persistent and paranoid," psychiatrist Willard Gaylin memorably wrote in *Nation*, "but that is precisely the stuff successful reformers are made of."

**Brought about a limit to the amount of resident physicians’ working hours in the USA.**

*(New York State Department of Health Code, Section 405, also known as the Libby Zion Law)*
Chapter 3

Essentials of Airway Management

Airway management is essential
Any of the three components of modern day anaesthesia results in loss of airway control
Components of a general anaesthetic

• Anaesthesia
  – Absence of consciousness / awareness

• Analgesia
  – Absence of pain / sympathetic stimulation

• Muscle relaxation
  – Absence of movement / motor reflexes

Any of these three groups in-and-of-itself causes loss of airway control
Indications for airway management

- **Physiological factors**
  - Central nervous system suppression (Glasgow coma scale ≤ 8/15)
  - Loss of muscle tone
  - Loss of reflexes (loss of airway sensation)
  - Ventilation - if intubation is not indicated
  - Prolonged procedures cause atelectasis and accumulation of secretions. These conditions often need lung recruitment and toilet and are actually indications for intubation.
  - Patients of the *exremes of age* have anatomical and physiological factors that make them more prone to loss of the airway, decreased muscle tone, and decreased airway reflexes.

- **Pharmacological factors**
  - Loss of airway sensation (topical anaesthesia)
  - Neuromuscular block
  - All central nervous system suppressants cause a dose-dependent loss of airway tone.

You may have noticed that unconsciousness is one of the main indications for airway management. All patients with a Glasgow Coma Scale of ≤ 8/15 must be intubated and ventilated. This forms part of neurological resuscitation and the prevention of secondary brain injury in the patients who have sustained brain injuries. Remember: the most common cause of coma is general anaesthesia. Therefore, general anaesthesia is the most common indication for airway management and ventilation.

While reading the rest of this chapter, you must constantly keep the following aspects of the airway in mind and integrate them:

- **The anatomy of the airway**
- **The physiology of the airway**
- **The pharmacology of the airway**

**Monitoring of the airway:** are the indications and methods of airway management appropriate and safe? In this regard, pulse oximetry and capnography (see Chapter 4) is indispensable. Briefly, the pulse oximeter measures the oxygen saturation of arterial blood. There is a very good agreement between the saturation displayed by the pulse oximeter (SpO₂) and arterial oxygen saturation (SaO₂).

From the capnograph, samples gas from the filter between the airway and the anaesthetic circuit (the tubing system connecting the patient airway to the anaesthetic machine). When the patient exhales the gas contains CO₂ and when the patient inhales, the gas contains a little (rebreathing system or circuit) or no CO₂ (non-rebreathing or circle system). The CO₂ in the gas is analysed by the capnograph and displayed on a graph (the capnogram) with CO₂ on the y axis and time on the x axis. If the CO₂ does not increase during expiration, the patient is not breathing, there is an obstruction in the airway, the artificial airway is not functional (e.g. oesophageal intubation), disconnection between the airway and anaesthetic circuit, or a disconnection of the capnograph sampling cannula. For a discussion on capnography and oximetry, see Chapter 4.

**ANATOMY**

In this section, the anatomy that is pertinent to management of the airway is discussed. Please look at the relevant structures in your anatomyAtlas. The airway refers to the continuous tube and is divided into two parts:

- **The upper airway** stretches from the lips and nostrils to the vocal cords.
- **The lower airway** consists of the trachea and bronchi.

The level of the sixth cervical vertebra is an important landmark as this is the junction between the larynx and trachea. All the parts of the airway are composed of a *lumen, wall, and structures outside the wall* (Figures 1 and 2). The wall consists of mucosa, muscle, and cartilage (honey or cartilaginous). The airway is in

- **GCS < 8 = intubation**
- **Most common cause of coma is general anaesthesia**
- **General anaesthesia is the most common indication for airway management**
Methods of airway management

- Face mask (FM)
- Laryngeal mask airway (LMA)
- Endotracheal tube (ETT)

Regarding acute airway management, the priorities are patency and protection of the airway.

Pre-induction equipment check
Before you embark on airway management, the equipment necessary to create, maintain, and secure the airway must be immediately available:

- An assistant. Do not do airway management on your own.
- The anaesthetic machine must have been checked.
- Suction.
- The theatre table must be in working order.
- An intubation pillow (about 10 cm thick for adults and 5 cm for children)
- Laryngoscope with a choice of blade sizes
- Stylet and Magill forceps
- An oral airway and laryngeal mask airway (LMA) (see Table 1)
- An endotracheal tube of which the cuff has been tested for a leak must be on the anaesthetic machine. A tube of one size smaller must also be available.

The indication for airway management determines the method or route (Tables 1 to 3). These methods are supraglottic, transglottic, and transtracheal.

- Supraglottic (Table 1): These open the airway up to the hypopharynx. Supraglottic airways are inserted with the knowledge what path they follow, but usually not under direct vision; they are inserted blindly and may be used when inspection of the airway (pharynx and vocal cords) is not possible. Therefore, supraglottic airways are often used when laryngoscopy has failed and/or as emergency airways. They do not ensure patency of the rima glottidei, such as anatomical lesions and laryngospasm. All the translaryngeal supraglottic airways keep the upper and lower jaws apart and therefore prevent swallowing. They can also, irritate the pharynx, cause coughing, vomiting, and laryngospasm and therefore promotes aspiration – especially in the lightly anaesthetized patient. Therefore, they create and maintain the upper airway but do not protect the airway. They do not protect the airway from aspiration. They are often used to create and maintain an airway in an emergency, e.g., cannot intubate cannot ventilate (CICV). The supraglottic airways are contraindicated in elective (planned) surgery if the patient:
  - If the patient runs the risk to regurgitate and aspirate;
  - If the patient is operated in any other position than the position;
  - If the patient runs must be ventilated during the procedure.
  - When the airway is shared with the surgeon or when you will be unable to reach the airway during surgery (head and neck surgery)

- Translaryngeal (Table 2): “Endotracheal tubes” (ETT) is the collective term for tubes that are inserted via the mouth or nose into the trachea. These tubes remain the safest and most predictable airways. Insertion of translaryngeal airways requires direct or indirect (fiberoptic) laryngoscopy.
  - If one knows how, or is lucky, an ETT can be inserted blindly. Translaryngeal airways create, maintain, and protect the airway, and allow ventilation. Bronchoscopy and bronchial toilet can be done through the straight tubes but not through RAE tubes. The number of the tube refers to the inner diameter in mm. The size inserted is determined by the size and age of the patient. Men are usually intubated with Nr 8 to Nr 9, and women with Nr 7 to Nr 8. For paediatric sizes, see Chapter 22.

- Infraglottic (Table 3): These airways are obtained electively or in the CICV scenario. These are surgical airways where an airway is passed into the trachea under vision.
A face mask is a
An laryngeal mask is a mask that fits fairly snugly over (not inside) the opening of the trachea, but not sealing off the trachea, and not tightly enough for high ventilatory pressures to be applied, and with the risk of inflation of the stomach and/or obstruction of the airway, and in selected patients, with the risk of pulmonary aspiration of gastric content even while the cuff remains inflated.
An endotracheal tube is a tube that fits snugly into (not against) another tube (the trachea) sealing off the trachea tightly so that high ventilatory pressures can be applied, without the risk of inflation of the stomach or obstruction of the airway, and without the risk of pulmonary aspiration of gastric content while the ETT remains in position and the cuff inflated.
Vallecula
Space where tip of MacIntosh laryngoscope blade is placed
The LMA remains outside the glottic opening!

The ETT passes through the glottic opening!
When evaluating the airway think of 3 separate components

1. Ventilation

2. Laryngoscopy and intubation

3. Rescue airway
Face mask ventilation
- maintenance using one hand -

- Head tilt
- Chin lift
- Jaw thrust
- Sniffing position
- Head tilt-chin lift
Face mask ventilation
- maintenance using two hands -
Patient awake

- Vocal cords
- Epiglottis
- Tongue
- Hard palate
- Soft palate
- Nasopharynx
- Oropharynx
- Hypopharynx
- Trachea
- Larynx
Patient anaesthetised
Laryngospasm

Prolonged intense glottic closure due to adduction, constriction and backward movement of the epiglottis

- Occurs in response to stimulation (reflex)
  - Local
  - Remote
- The reflex persists after stimulation has been removed
Features associated with difficult face mask ventilation

- Beard
- Obesity
- No teeth
- Elderly
- Sleep apnoea
Features associated with difficult face mask ventilation

- Beard
- Obesity
- No teeth
- Elderly
- Snore
Remember “BONES”
Failed **face mask** ventilation?

Attempt **laryngeal mask** ventilation
• May the LMA be used in children?
• Is the LMA sometimes placed in the oesophagus?
• May the LMA be used for PPV?
...see...  ...think...
**LMA (vs FM)**

**Advantages**
- Hands free
- Better seal (beard)
- Easier to maintain airway
- Protects against airway secretions
- Less facial nerve and eye injuries
- Less operating room pollution

**Disadvantages**
- More invasive
- More risk of airway trauma
- Requires new skill
- Deeper anaesthesia required
- Some TMJ mobility required
- N\textsubscript{2}O diffusion into cuff
- Multiple contra-indications
Features associated with difficult insertion of an LMA

- Mouth opening
- Intra-oral tumours
When evaluating the airway think of 3 separate components

1. **Ventilation**

2. Laryngoscopy and **intubation**

3. **Rescue** airway
Direct laryngoscopy

Trigeminal nerve  Glossopharyngeal nerve  Vagus nerve
Direct laryngoscopy

**Figure 4a** The line of vision with the head in the sniffing position

**Figure 4b** Interruption of the LOV by:
1. An anterior larynx
2. Inability to open the mouth; prominent teeth which shifts the line upwards
3. A large tongue, tongue tumours, supra- and infrahyoidoide tumours or infection (Ludwig angina)
   - Intractable tongue, or small mandible (protruding tongue); palatal tumours
4. Retropharyngeal lesions (retropharyngeal haematomata, sepsis, Ludwig angina), prevertebral haematomata, sepsis
1 to 4. Poor positioning; inability to open the mouth, flex the neck or to extend the atlanto-occipital joints (sniffing position)
Prediction of difficult laryngoscopy and intubation

Any factor that interrupts direct visualization of the glottic opening.
Not immediately life-threatening airway obstruction

- Fell from bicycle
- Bruising anterior neck
- Immediate emhysema
- Pneumothorax

Pt with suspected neck injury
? Appropriate airway maneuver
Not immediately life-threatening airway obstruction

Spontaneous ventilation

Tear in lower trachea
Features associated with difficult direct laryngoscopy

The definitive diagnosis of OSA is made with polysomnography in the sleep laboratory. The test is cumbersome and can be predicted using the STOP BANG questionnaire. A count of ≥ 3/8 indicates a high risk of OSA.1

Do you SNORE loud enough to be heard through closed doors?
Do you often feel TIRED, fatigued, or sleepy during daytime?
Has anybody OBSERVED you stop breathing during your sleep?
Do you have or are you being treated for high blood PRESSURE?
BMI > 35 kg m⁻²?
AGE > 50 years?
NECK circumference at cricoid > 40 cm?
GENDER male?

Clinical tests to predict the ease of laryngoscopy
Several clinical predictors of a difficult laryngoscopy have been described. However, the following factors confound their utility.
• On its own, each predictor has poor sensitivity and specificity.
• The tests are very subjective (large inter-observer variability).
• All anaesthetists do not define the “difficult airway” the same.

The sensitivity and specificity of these tests improve when they are combined into a core, e.g. the Wilson score.2 The Wilson score takes into account five variables. They are graded subjectively () from 0 to 2 where 0 is normal and 2 abnormal. A count of ≥ 2 has a true positive value of 75% and a false positive predictive value of 12% (Table 4).

Table 4 The Wilson score

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Level</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass</td>
<td>0</td>
<td>&lt; 90 kg</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>90 kg to 110 kg</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>&gt; 110 kg</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>&gt; 90°</td>
</tr>
<tr>
<td>Head and neck movement</td>
<td>1</td>
<td>About 90° (±10°)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>&lt; 90°</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>IG ≥ 5 cm* or SL &gt; 0</td>
</tr>
<tr>
<td>Jaw movement</td>
<td>1</td>
<td>IG ≤ 5 cm and SL = 0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>IG &lt; 5 cm and SL &lt; 0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Normal</td>
</tr>
<tr>
<td>Receding mandible</td>
<td>1</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Severe</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Normal</td>
</tr>
<tr>
<td>Back teeth</td>
<td>1</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Severe</td>
</tr>
</tbody>
</table>

IG, inter-incisor gap; SL, subluxation of the temporomandibular joint; *5 cm = 3 fingers

If possible, the following clinical tests to predict the ability to do a successful laryngoscopy should be performed in all patients preoperatively:

1. Inter-incisor gap
Ask the patient to open their mouth as wide as possible. A distance of less than two fingers breadths (3cm) between the upper and lower incisors or alveolar ridges is associated with difficult laryngoscopy.

2. Protrusion of the mandible
Ask the patient to protrude their mandible. Inability to protrude the lower incisors in front of the upper incisors predicts a difficult laryngoscopy. This is called prognathia.

3. Mallampati score
The Mallampati score is done in an awake. The patient is asked to open the mouth and protrude the tongue. The patient must not phonate or extend the head. The view of the uvula is recorded (Figure 6). This score evaluates the ability to open the mouth, the size and mobility of the tongue, and any mass in the passage between the mouth and fauces:

- Disproportion
- Distortion
- Dysmobility
- Dentition
Features associated with difficult direct laryngoscopy

- Disproportion
- Distortion
- Dysmobility
- Dentition
Remember the four “Ds”

Approach to distorted airway?
• Awake fibre-optic intubation
• Gas induction (Volatile induction with spontaneous breathing)
using a mirror or a fibreoptic instrument. ENT surgeons often do this. This can also be done before induction of anaesthesia in theatre, using a laryngoscope, the anaesthetist may get an idea of the visibility of the vocal cords.

What the anaesthetist observes during laryngoscopy after induction of anaesthesia is often predictable from the preoperative airway evaluation. However, in about 2% of laryngoscopies this can be an unpleasant surprise.

The direct laryngoscopic view of the vocal cords in the anaesthetized patient is graded using the Cormack and Lehane Classification (Table 5 and Figure 7). The laryngoscopic view should be documented on the anaesthetic record. The anaesthetist must review previous anaesthetic records during the preoperative assessment. If a high Cormack and Lehane grade has been documented, steps can be taken to facilitate airway management during subsequent anaesthetics.

Table 5 Cormack Lehane grading of direct laryngoscopic view

<table>
<thead>
<tr>
<th>Grade</th>
<th>Vocal cords</th>
<th>Epiglottis</th>
<th>Base of tongue</th>
<th>Posterior pharynx wall</th>
<th>Oesophageal inlet</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Whole</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Cannot get round the corner, the cords are high up behind the base of the tongue. These views improve with better positioning of the head and neck (sniffing position). The McCoy laryngoscope blade may be helpful. You will need a ‘hockey stick’ stylet inside the endotracheal tube to insert the tube. Intubation is difficult, blind, or may be impossible.</td>
</tr>
<tr>
<td>II</td>
<td>Partially</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

DIFFICULT AND FAILED AIRWAY MANAGEMENT

The aim of airway management is to fulfill the indication of the airway management in the particular case, namely creation, maintenance, protection, and ventilation. If one of these is not possible, there is failure of airway management.

Airway management can fail due to inability to insert the supraglottic, translaryngeal, or transtracheal airway device and/or failed laryngoscopy. These can result from anatomical factors (outside the wall, in the wall, in the lumen) from the nose or mouth to the trachea.

"Failed insertion and/or laryngoscopy” refers to, e.g. the situation where laryngoscopy is easy but one cannot insert an ETT. This occurs typically with infra glottic lesions such as tracheal stenosis or compression by a mediastinal mass, or when insertion of an ETT is temporarily contraindicated, e.g. in the presence of foreign body in the airway. If one cannot insert a supraglottic airway, e.g. an LMA, airway management has also failed.
Evaluation for ease of laryngoscopy

- Inter-incisor gap
- Prognathia
- Mallampati score
- Craniocervical movement
- Patil’s test
- Sternomental distance
- Mandibular space
- NC / TM ratio
Mallampati score
[size of the tongue relative to the pharynx]

I and II predict easy intubation
III and IV predict potentially difficult intubation

Limitations during late stages of pregnancy
# LMA (vs ETT)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Less invasive</td>
<td>• Increased risk of pulmonary aspiration</td>
</tr>
<tr>
<td>• Less anaesthetic depth required</td>
<td>• Prone or jackknife positions</td>
</tr>
<tr>
<td>• Useful in difficult intubations</td>
<td>• Unsafe in morbidly obese</td>
</tr>
<tr>
<td>• Less tooth and laryngeal trauma</td>
<td>• Limits maximum PPV</td>
</tr>
<tr>
<td>• Less laryngo- and bronchospasm</td>
<td>• Less secure airway</td>
</tr>
<tr>
<td>• Muscle relaxation not required</td>
<td>• Greater risk of gas leak and pollution</td>
</tr>
<tr>
<td>• Neck mobility not required</td>
<td>• Can cause gastric distention</td>
</tr>
<tr>
<td>• Less effect on intra-ocular pressure</td>
<td></td>
</tr>
<tr>
<td>• No risk of esophageal or endotracheal intubation</td>
<td></td>
</tr>
</tbody>
</table>
When evaluating the airway think of 3 separate components

1. **Ventilation**

2. **Laryngoscopy and intubation**

3. **Rescue** airway
Rescue airway

- Surgical cricothyroidotomy
- Needle cricothyroidotomy

If potential difficulty is recognized, the cricothyroid membrane should be identified and marked BEFORE any airway intervention is undertaken.

Are you familiar with the surface anatomy of the cricothyroid membrane?
Features associated with difficult cricothyroidotomy and tracheostomy

- Flexion
- Deviation
- Disease
- Devices
Evaluation of the airway

(KEEP IN MIND THE 3 SEPARATE COMPONENTS)

• History
  – Previous anaesthetics

• Clinical examination
  – General examination
  – Predictors of difficult
    • Face mask ventilation
    • Laryngoscopy
    • Rescue airway
  – Specific evaluations
    • Mallampati
    • Patil
    • Other
Explain the terms *inspire* and *expire*.

"When you breathe you inspire, and when you don’t breathe you expire”

When you drink and drive you also expire.
Which physician is best skilled for airway management?

The one that daily deals with it
Specialist anaesthetist

Thorough knowledge of

• Applied physiology
  – And changes due to disease processes

• Applied pharmacodynamics / pharmacokinetics
  – And changes due to disease processes

• Applied physics
  – Gases / fluids

• Technical skills – numerous
  – Most important = *airway management*