Management of the airway and ventilation during resuscitation

D. A. GABBOTT AND P. J. F. BASKETT

The management of the airway and ventilation is a vital component in the resuscitation of patients with respiratory and cardiac arrest.

In recent years considerable emphasis has been placed on the cardiac and vascular elements of resuscitation as the value of early defibrillation has become appreciated as the principal element in producing a return of spontaneous circulation in those with cardiac arrest. Nevertheless, the role of maintaining oxygenation during the resuscitative process is no less important in order to ensure protection of the vital organs from hypoxic damage. In June 1996 the Airway and Ventilation Management Working Group of the European Resuscitation Council published their guidelines for the basic and advanced management of the airway and ventilation during resuscitation. Since then several national resuscitation councils in continental Europe, the UK, Australasia and Southern Africa have adopted these guidelines in principle.

The airway in resuscitation

Airway obstruction may be a prime cause of cardio-respiratory arrest or may occur as a consequence of unconsciousness. Common causes are listed in figure 1. Untreated, the wholly obstructed airway will, within a very short period (generally accepted as 2–5 min except in unusual circumstances, e.g. hypothermia or intoxication with sedative or opioid drugs) cause neurological or other vital systemic damage which may be irreversible or fatal.

BASIC ASSESSMENT

Assessment of the airway is based on a check for unresponsiveness, examining chest movements and feeling for air flow from the mouth and nose. The assessment should be made in the position in which the patient is found, especially if trauma is suspected (see below). If breathing is absent the patient should be turned to the supine position (using manual in-line stabilization of the head and neck if there is a potential cervical spine injury). The head and neck

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**Figure 1** Common causes of airway obstruction.

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**Key words**


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D. A. GABBOTT, MA FReA, Gloucestershire Royal Hospital, Great Western Road, Gloucester GL1 3NN. P. J. F. BASKETT, BSc FReA, MRCP, Frenchay Hospital, Bristol BS16 1LE.
should be aligned in the clear airway position using head and chin lift tilt (omitted if there is a possibility of cervical spine injury), and jaw thrust. Ideally, the head should be placed on a small pillow to achieve the “sniffing the morning air position”. When the head and neck are aligned the assessment should be complemented by seeking other signs, such as cyanosis, pallor, excessive salivation, gastric contents or foreign body in the mouth or pharynx, and evidence of head, maxillofacial, neck or chest trauma. Abnormal phonation or breath sounds and wheeze or stridor indicate a particularly obstructed airway.

Stridor occurring during inspiration generally indicates obstruction above the larynx, wheeze occurring during expiration usually indicates obstruction below the larynx. A suggested plan for assessment of the airway and breathing is shown in figure 2.

**Management of the upper airway obstructed by foreign material (choking)**

**CAUSES AND SIGNS**

In adults the commonest causes are aspiration of
gastric contents or blood associated with loss of the protective laryngeal reflexes and choking on large portions of poorly chewed food. In children and the mentally challenged, a large number of other ingested articles may be added to these causes, for example peanuts, marbles, pen tops, beads, etc. Choking is heralded by respiratory distress, stridor, wheezing and coughing. As the obstruction becomes more complete, airflow is reduced, the patient is unable to speak or breathe and cyanosis occurs. Unconsciousness supervenes and death occurs if the obstruction is not relieved immediately. The patient may clutch or point to his or her neck—a universal distress signal for imminent choking.

MANAGEMENT
While there appears to be adequate air movement the patient should be encouraged to cough and be observed closely. Oxygen, if available, should be administered. If air movement is poor or absent and the patient becomes cyanosed, immediate positive action is required. The obstruction may be cleared by head and neck alignment, back blows, abdominal or chest thrusts, lateral positioning or finger sweeps, or by using a laryngoscope with suction, Magill forceps or a Kelly clamp to remove the obstruction under direct vision. As a last resort upper airway obstruction may be bypassed by a surgical airway using cricothyroidotomy or needle jet ventilation provided the appropriate skills and equipment are available.

**Back blows**
A series of five back blows are applied during expiration with the patient standing, sitting or in the lateral position. Preferably the head should be positioned below the chest to achieve the best gravitational drainage advantage. Children should be placed prone with a head down tilt on the rescuer’s thigh or arm. If this fails to clear the obstruction, abdominal thrusts should be used.

**Abdominal thrusts (Heimlich manoeuvre)**
Abdominal thrusts may be applied with the patient standing, sitting or lying down in the supine position. The supine position is used in unconscious

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**Figure 3** Algorithm for the management of upper airway obstruction caused by foreign material (choking).
patients and in the very obese or when the rescuer finds it impossible to encircle the abdomen of the victim. Abdominal thrusts may result in damage to the abdominal viscera or gastric regurgitation. The technique is not recommended in infants and small children in advanced pregnancy.

The guidelines of the American Heart Association do not recommend the application of back blows in adults (although they do in infants and small children) and prefer early application of abdominal thrusts. European, Australasian and Southern African guidelines advocate the application of back blows before abdominal thrusts.

Chest thrusts

Chest thrusts are preferred in children and when abdominal thrusts are contraindicated or ineffective. Rhythmic thrusts are applied with both hands to the anterior aspect of the chest in the same position as used for external chest compressions.

Finger sweeps

Finger sweeps should be used only in the unconscious victim who does not have good reflexes or the ability to bite the rescuer’s finger. The patient should be placed in the lateral position. Blind sweeps are not generally recommended in infants and small children because of the risk of deeper impaction of the foreign body at the laryngeal level but sweeps using the little finger to extricate an obvious object under direct vision are acceptable. An algorithm for the management of choking is shown in figure 3.

The recovery position

The recovery position is used in unconscious patients with adequate spontaneous breathing to maintain a patent airway and reduce the possibility of aspiration of gastric contents or foreign material in the mouth or pharynx. Several different recovery positions have been advocated (dependent arm behind or in front of the trunk, uppermost arm extended or flexed to place the hand under the cheek, dependent leg extended or flexed, uppermost leg extended or flexed). It has proved impossible to obtain universal international agreement as to the best position but there is consensus as to the principles involved. These principles include:

- The patient should be in as near a true lateral position as possible with the mouth dependent to allow free drainage of fluid.
- The position should be stable.
- Any pressure on the chest that impairs breathing should be avoided.
- Care should be taken to avoid compromise of the circulation in either arm or peripheral nerve compression in the arms and legs.
- It should be easy to turn the victim into the lateral position and return to the supine position, having particular regard to the possibility of injury to the cervical spine.
- Good observation and access to the airway should be possible.

MANAGEMENT OF THE AIRWAY IN PATIENTS WITH SUSPECTED SPINAL INJURY

Great caution must be taken in aligning the head and neck in any trauma victim requiring resuscitation. In these circumstances the cervical spine must be maintained in a neutral mid-line position unless it is physically difficult to do so or resistance is encountered during any attempt at realignment. Manual in-line stabilization is the technique of choice in any trauma patient, with the head grasped firmly at the mastoid processes and the occiput. Traction should be avoided as it may distract the cervical spine and cause more neurological damage. Jaw thrust is the only basic airway opening manoeuvre appropriate for any patient with suspected cervical spine injury. Suction and use of forceps under direct vision using a laryngoscope with the head and neck maintained in the neutral position are the best methods of removing foreign material from the mouth and pharynx but back blows and abdominal or chest thrusts are acceptable only in extreme conditions. The risk of hypoxic damage from airway obstruction in an unconscious breathing victim is likely to outweigh the risk of aggravating cervical spine injury in the vast majority of cases and such patients should be placed in the lateral position using a log rolling technique with a minimum of four attendants. The rescuer controlling the head and neck with manual in-line stabilization should be in command of the rotation procedure. When turned, the lower limb should not be flexed unless a thoracolumbar injury is not suspected. Movement of the arms is not recommended.

Basic management of ventilation

In basic resuscitation the method of choice is expired air ventilation using the mouth-to-mouth, mouth-to-nose, mouth-to-mouth-and-nose (neonates) or the mouth-to-mask method. The mouth-to-mask method has aesthetic advantages and may reduce the possibility of cross infection between patient and rescuer. Some models of mask permit the addition of oxygen if available. The lhistoire recommended sequence of ventilations in relation to external chest compressions in patients with cardiac arrest has been 1:5 (using two rescuers) and 2:15 (using a single rescuer). Recently, the European Resuscitation Council has recommended that only the single rescuer method (2:15 sequence) should be taught to lay people using the justification that the second person’s priority should be to seek and provide help (especially a defibrillator) and that two lay people may find co-ordination of chest compressions and ventilations difficult unless they have practised together regularly. This teaching is likely to be followed on a global scale by authorities in Australasia, Southern Africa, the United States, Canada, Latin America and the Pacific Rim. While there is consensus regarding the technique of application of expired air ventilation there is debate as to the sequence in relation to chest compressions, inflation flow rate and volume of ventilation.
SEQUENCE OF VENTILATIONS AND CHEST COMPRESSIONS

Early guidelines from the American Heart Association (AHA) proposed that four ventilations should be given at the beginning of resuscitation using a “step-on-step” technique of applying each subsequent inflation before exhalation was complete, thus introducing a form of positive end-expiratory pressure (PEEP). The rationale behind this practice was the postulation that alveolar collapse occurred with cardiorespiratory arrest and that application of PEEP would improve the situation. The “step-on-step” technique for the first four breaths was rescinded in the guidelines of 1986 in the face of evidence that this method generated high proximal airway pressures and that the lower oesophageal sphincter opening pressures were likely to be reduced. Both of these factors were likely to increase the risk of gastric regurgitation and subsequent pulmonary aspiration. The 1986 AHA standards and guidelines reverted to initial application of two normally spaced breaths followed by a one-rescuer sequence (15 compressions/two ventilations) or a two-rescuer sequence (five compressions/one ventilation).

Clearly the 15:2 or 5:1 sequences which were proposed in the late 1950s were based on a concept of normal cardiorespiratory physiology. However, this state of affairs is unlikely to apply in cardiorespiratory arrest when delivery of carbon dioxide to the lungs is likely to be low, so reducing the emphasis on ventilation frequency and volume. What is paramount, however, in cardiac arrest is oxygenation and there is a need for research to establish the best compromise to provide satisfactory oxygenation and carbon dioxide removal under these conditions.

For the future it may be that the frequency of ventilation can be reduced to a sequence of 1 in 10 or even 1 in 20 interpolated with external chest compressions while oxygen is insufflated into the lungs. However, in the absence of new positive scientific evidence the principle of adherence to the present recommendations applies.

VENTILATION FLOW RATES AND VOLUMES

Ventilation through an unprotected airway whether using the expired air technique or a self-inflating bag-valve-mask carries a very high risk of gastric inflation and subsequent pulmonary aspiration. Evidence of aspiration has been found in approximately 28% of failed resuscitations examined by the coroner. Weiler, Heinrichs and Dick reported evidence of gastric inflation in two of 31 anaesthetized patients with an unprotected airway ventilated by experts and recommended that inflation pressures should be limited to 20 cm H2O. The following factors are relevant in considering the possibility of gastric inflation during resuscitation.

- Alignment of the head and neck.
- Lower oesophageal sphincter opening pressures.
- Proximal airway pressure during inflation.

Optimal alignment of the head and neck has been discussed above. The lower oesophageal sphincter opening pressure has been estimated to be in the region of 20 cm H2O in live patients. In swine subjected to experimental cardiac arrest the oesophageal sphincter opening pressure decreased from 26 to 4 mm Hg. Although there are no comparable data for humans it is likely that a similar decrease occurs as suggested by the high incidence of regurgitation reported during cardiac arrest.

The proximal airway inflation pressure during intermittent positive pressure ventilation is related to the inflation flow rate and tidal volume.

The recommendations of the AHA stipulate that either a tidal volume sufficient to make the chest rise normally, or 800–1200 ml, should be applied over 1–2 s at a rate of approximately 10 bpm. Clearly these numerical volumes aim to achieve hyperventilation.

Training manikins equipped with auditory and visual signals hitherto have been set to conform to tidal volumes of 800–1200 ml. Analysis of these numerical recommendations, however, reveals several difficulties. To maintain inflation pressures at reasonable values (approximately 20 cm H2O) a tidal volume of, say, 1000 ml requires at least 2.5 s for inflation and another 1 s for exhalation using a single rescuer. Longer times are needed for patients with reduced compliance. Thus two ventilations last at least 7 s, 15 external chest compressions applied at a rate of 80 per minute last 12 s, and therefore the total time for each sequence is (7 + 12) 19 s. Just over three sequences are completed in 1 minute (i.e. six breaths and 45–50 chest compressions) and while six breaths per minute may be adequate during cardiac arrest, it is unlikely that 45 chest compressions provide a viable circulation. Similar calculations can be performed for a 1:5 sequence with similar results.

In considering the alternative component of the recommendations, clinical observation of the chest, it is important to determine the tidal volume associated with a “normal” breath. Baskett, Nolan and Parr showed in anaesthetized patients that adequate chest movement perceived by nurse and medical observers was produced by tidal volumes of 400–500 ml. Calculating the number of chest compressions and ventilations using a tidal volume of, say, 500 ml with the same inflation rate, each sequence would take 3.5 s (two breaths) plus 12 s (15 compressions) = 15.5 s, resulting in just under four sequences per minute, totalling eight breaths and 60 chest compressions.

In clinical resuscitation practice the tidal volume applied is gauged by the rise and fall of the chest and is likely to be approximately 400–500 ml rather than the 800–1200 ml required in manikin practice. It is likely that many victims have survived using tidal volumes of 400–500 ml during resuscitation and certainly the minute volumes generated are more than adequate to clear carbon dioxide during anaesthesia with a normal cardiac output.

For this reason the European, Australasia and Southern African Resuscitation Councils have recommended a tidal volume of 400–500 ml (5–6 ml kg−1) during resuscitation and that training manikins with visual or auditory signals, or both, should...
Many questions remain in this field and can be answered only by research studies which are not easy in patients undergoing resuscitation. Perhaps even smaller tidal volumes would suffice to eliminate carbon dioxide? Would higher compression rates (100–120 per minute) produce better perfusion of vital organs and improved survival rates? Would simple insufflation of oxygen through a patent airway such as a laryngeal mask or tracheal tube provide adequate oxygenation? Given sufficient inspired oxygen concentrations, do standard chest compressions provide adequate pulmonary ventilation to remove the carbon dioxide that is being delivered to the lungs under these circumstances? Or would active compression and decompression of the chest (ACD CPR) using a device such as the Cardiopump (Ambu) be more effective? Does Vest CPR (Cardiologic Systems) provide adequate pulmonary ventilation? These and other questions require an answer before more definitive recommendations can be made in such a fundamental matter as the optimal method of producing satisfactory oxygenation and removal of carbon dioxide during resuscitation. A flow chart for basic management of the airway and ventilation is shown in figure 4.

**Advanced management of the airway and ventilation during resuscitation**

Advanced airway management is required if basic
Management of the airway and ventilation

Techniques are proving inadequate or more experienced personnel and equipment are available. Any technique can be described as advanced if it involves the use of adjuncts, and the European Resuscitation Council (ERC) has recently published guidelines on the subject. The use of advanced airway techniques ultimately must be a personal choice depending on the training and experience of the individual concerned.

The ERC algorithm for advanced airway management (fig. 5) begins with the apnoeic patient or an unprotected airway. Clearly basic life support measures may be in progress, for example mouth-to-mouth ventilation or, if the hospitalized patient has developed an immediate need for airway management, advanced techniques may be applied in the first instance.

ADVANCED AIRWAY ADJUNCTS AND TECHNIQUES

Oral and nasopharyngeal airways

These are the simplest of the advanced airway adjuncts. They are easy to insert and help provide a

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Figure 5 Flow chart for advanced management of the airway and ventilation. *Tracheal intubation is best; the laryngeal mask airway or Combitube are initial alternatives.
patent airway by limiting obstruction by the tongue. They need to be appropriately sized, positioned correctly and used in the relevant circumstances. Oral and nasal airways that are too short are ineffective and those that are too long may provoke laryngeal spasm. Oral airways are poorly tolerated in semi-conscious patients with active gag reflexes and may be difficult to insert in patients with clenched jaws. The nasal airway is often better tolerated in these circumstances. The oral airway can be inserted using the familiar rotational method or with a tongue depressor, which is the favoured method when dealing with children. The nasal route must be used (if at all) with extreme caution in victims of trauma, particularly if a base of skull fracture is suspected. Placement of nasal airways into the cranial vault has been described,24 furthermore the nasal route is far more likely to cause haemorrhage than the oral route. A recent modification of the oral airway includes a pharyngeal cuff. The COPA airway (Mallinkrodt Ltd) has a standard 22-mm connector and may allow ventilation via a self-inflating bag or anaesthesia system. None of these devices offers any protection from regurgitation of gastric contents.

**Cricoid pressure**

It is now clear that regurgitation and aspiration must be considered as major hazards during resuscitation if the airway is unprotected. Cricoid pressure represents a protective measure during basic airway management until advanced methods can be applied. The technique is easily taught but requires re-evaluation as many who have been trained in applying it provide widely differing forces to the cricoid cartilage.44 Recent work suggests that the original value of 44 Newtons required to prevent regurgitation is excessive and a value of approximately 30 Newtons is appropriate.78 The presence of an oro- or nasogastric tube has been shown in cadaver studies to increase the efficiency of protection provided by cricoid pressure and it should therefore be left *in situ*.65 78

The use of cricoid pressure is not without potential problems. If attempts are made to ventilate a patient’s lungs manually using a face mask, after applying pressure to the cricoid cartilage, there may be significant reduction in expired tidal volume and an increase in peak inspiratory airway pressure. Furthermore, complete airway obstruction may occur in up to 10% of cases.2 This may be because of direct airway compression if cricoid pressure is excessive or applied incorrectly. Furthermore, if pressure is applied in a caudal direction (which occurs if the patient’s head is flexed on a pillow) this may cause closure of the laryngeal inlet via a rotational effect on the arytenoid cartilages12 (R. Vanner, personal communication). Cricoid pressure may also cause relaxation of the lower oesophageal sphincter making regurgitation more likely if pressure is applied poorly or released transiently.75

Pressure can be applied with one hand or bimanually with a hand supporting the posterior cervical spine. Recent work suggests that the single-handed technique provides just as good a view at laryngoscopy as using two hands.15 However, supporting the cervical spine with a hand placed beneath the neck is clearly of potential benefit in any victim of trauma with a suspected broken neck. In another recent study, single-handed cricoid pressure caused significant movement of the neutrally positioned cervical spine26 confirming that in trauma patients, at least, some posterior support of the cervical spine is indicated. Finally, if tracheal intubation is difficult or impossible, the use of other airway adjuncts (e.g. laryngeal mask airway) in the presence of cricoid pressure may be impaired.48

**Tracheal intubation**

The gold standard for advanced management of the airway during resuscitation is tracheal intubation. This provides a clear and secure airway allowing ventilation, oxygenation and suction. The skill of intubation is not easily taught, requires constant practice and the technique is not without complications if performed poorly or attempts are prolonged. There are a vast array of aids to intubation to help with the difficult airway, including laryngoscopes, bougies, stylets and light wands. Of the currently available accessories, the gum elastic bougie and McCoy laryngoscope appear to be two of the more useful, particularly in cases of difficult intubation of the trauma victim. The gum elastic bougie has been shown to reduce significantly the failure rate of oral tracheal intubation in patients where manual in-line stabilization and cricoid pressure were applied25 despite a slightly longer intubation time. The McCoy laryngoscope was introduced in 1993 and is available in sizes 3 and 4 for adults and more recently in sizes 1 and 2 for children. The laryngoscope causes elevation of the epiglottis from a fulcrum deep within the hypopharynx and requires less force than the Macintosh blade to expose the laryngeal structures.49 The McCoy laryngoscope has also been shown to reduce the stress response to laryngoscopy compared with the Macintosh blade.48 Studies have demonstrated that the laryngoscope improves the view at laryngoscopy compared with the conventional Macintosh blade and more importantly, the number of difficult views (grades 3 and 4) is reduced significantly.16 25 43 76

A variety of other intubation aids are available and include other laryngoscopes (e.g. Bullard, Upsherscope, Wuscope) and lighted stylets. An assortment of tracheal tubes are available with flexible tips (e.g. “Endotrol” tube), and a new stylet, the Rusch intubating stylet, allows the curve of a standard tracheal tube to be manipulated. The techniques of digital and blind nasal intubation have their advocates but both require considerable skill and constant practice. Nasal intubation is probably not appropriate for the trauma victim and furthermore, a survey of ATLS trained personnel revealed a poor success rate for intubation via this route.50 It is now clear that in experienced hands, oral intubation of the trachea is the preferred method, particularly for the trauma patient.18 64 66 The view at
laryngoscopy is also significantly improved if the cervical collar is removed and if there are enough personnel available this should be done while the neck is stabilized manually.

Confirmation of successful placement of the tracheal tube in resuscitation is of paramount importance and a variety of aids are available. The gold standard is undoubtedly capnography but misleading readings may occur because of reduced carbon dioxide delivery to the lungs in the arrested circulation. Furthermore, the apparatus is often not immediately accessible in resuscitation situations and more simple devices are appropriate. The oesophageal detector is such a device. It has been modified to include the use of an evacuator bulb and is highly sensitive at picking up oesophageal placement of a tracheal tube. A variety of colorimetric carbon dioxide detectors are also available, but these are not always accurate and may fail if there is not enough expired carbon dioxide. They may occasionally register a false positive result as a consequence of carbon dioxide in the stomach, either from poor basic life support techniques associated with gastric inflation or, more rarely, the presence of carbonated drinks in the gastric contents.

A more recent adjunct used for confirmation of successful tracheal intubation is the Scotti airway detector. The device sends sound waves down the tracheal tube and the reflected wave is detected. If the tube is in the trachea, which is hollow, then the reflected wave is different to that detected if the tube is in the oesophagus, which is collapsed. The concept, while simple, is not without problems. The device needs calibrating and a recent study has demonstrated that it is not very specific.

Finally, while the role of flexible fibreoptic laryngoscopy is limited in resuscitation situations, there are now hand-held, battery-operated fibreoptic devices (e.g. Rapiscope; Cook Critical Care Ltd) which, because they are readily portable, may find a role in confirmation of tracheal tube placement. The device has also been used to confirm correct placement of a needle or catheter passed through the cricothyroid membrane during formation of a surgical airway.

Laryngeal mask airway (LMA)

This airway device (fig. 6) has revolutionized anaesthetic practice since its introduction in 1988. More than 1000 scientific studies have testified to its satisfactory and versatile application in a variety of difficult circumstances. The device provides a clear airway without the need for laryngoscopy and it can be inserted from in front of the patient if necessary, which may be useful for victims of entrapment. Ventilation is more efficient and easier than with a bag and face mask and it can also be inserted with the neck maintained in a neutral position for patients in whom cervical spine trauma is suspected. The technique of insertion is easily taught to nurses, paramedics and doctors and the device has been used successfully by all of these groups in the management of cardiac arrest both in and outside the hospital.

Training on manikins has been shown recently to be just as effective as training on patients when learning the insertion technique and the recently introduced Portex introducer may encourage an even greater success rate for LMA insertion by non-anaesthetic personnel.

The LMA allows positive pressure ventilation provided it is applied carefully and airway pressures do not exceed 20–25 cm H₂O. In patients with poorly compliant lungs, for example those with pulmonary oedema, aspiration or obstructive airways disease, the lungs may not be ventilated adequately using the device. Inadequate protection of the airway is often quoted as a limitation of the LMA. However, evidence that pulmonary aspiration occurs in clinical practice is scant. In a multicentre study using the LMA at cardiac arrests the reported incidence of aspiration was only 1.5%. Furthermore, the LMA protects the airway against aspiration from sources above the larynx. This may have profound implications for some types of patients requiring resuscitation. In a recent study of trauma victims, those who aspirated, the vast majority aspirated blood. In nearly all cases this blood originated from sources above the larynx.

Another potential problem with the LMA is its ability to function adequately in the presence of cricoid pressure. There are several studies that have suggested that cricoid pressure impedes placement of the device. Furthermore, if cricoid pressure is released and then re-applied after insertion of the LMA, its function may still be impaired. A recent radiographic study showed that cricoid pressure caused upward displacement of the LMA which may allow its aperture to sit against the base of the tongue, thus impairing ventilation.

Despite this, the LMA remains an extremely useful device for resuscitation. Its ease of insertion and effectiveness suggest it should be used as a first-line airway adjunct for those who do not possess the skill to intubate the trachea, such as nurses and many doctors. If oral intubation is proving difficult the device may provide a route for intubation by allowing blind passage of a tracheal tube or gum elastic bougie down the lumen and into the trachea. The success rate for this procedure is variable however, with one study quoting a success rate of 96% and another only 26%. Preloading the LMA
with a tracheal tube or gum elastic bougie may reduce the failure rate of this technique. An intubating laryngeal mask has been designed and is currently undergoing multicentre clinical studies which may improve the intubation success rate using this principle.

**Oesophageal tracheal Combitube**

This device (fig. 7) is a double-lumen tube which is passed blindly into the mouth and allows ventilation of the patient’s lungs whether the tube enters the trachea or the oesophagus. There are apertures at a supraglottic level from the “tracheal” lumen and a distal opening from the “oesophageal” lumen. There is a small-volume distal cuff and a large-volume pharyngeal cuff. If the tube enters the trachea it can be used in the same way as any tracheal tube and the pharyngeal cuff is redundant. In the majority of cases however, the tube enters the oesophagus, in which case the distal and pharyngeal cuffs are inflated and ventilation is possible via the supraglottic side openings.

The Combitube may have certain advantages over some of the other airway adjuncts available. It requires no instruments for insertion, which makes it useful in difficult situations and locations. It occludes the oesophagus with a distal cuff and allows some “venting” of oesophageal contents via one of the two lumens. It can usually be inserted with the neck in a neutral position, making it potentially useful in trauma patients. Early studies using the device showed improvement in arterial oxygenation compared with tracheal intubation, probably because of a PEEP effect when ventilation is applied through the supraglottic apertures. It has been used successfully during cardiorespiratory arrest by intensive care nurses and paramedics with some success. Recently, the oesophageal detector device has been used to identify whether the Combitube has been passed into the trachea or oesophagus.

Potential problems include the size of the device; it is more difficult to insert than a laryngeal mask and insertion has not been evaluated formally in the presence of a cervical collar. The technique of insertion requires training and the stomach is inflated if ventilation is applied through the wrong aperture when the device is placed in the oesophagus. Because of its size, significant airway trauma appears to occur in some patients. In recent studies blood has been noted on the Combitube after removal in 24% and 45% (Gabbott, unpublished data) of patients. Airway pressures may also be higher when ventilation is attempted through the side holes. Finally, it has been suggested that ventilation is more effective with the head in a hyper-extended position. This presents a problem when dealing with trauma patients where the neck has to remain in a neutral position. Recent work, however, has demonstrated that the presence of a cervical collar does not appear to significantly impair ventilation (Gabbott, unpublished data).

The Combitube therefore remains an airway adjunct that, in theory, may prove to be useful. Further assessment is required before it can be advocated on a wide scale.

**Surgical airway**

Resort to the surgical airway is rarely necessary but is a skill that anyone with a claim to expertise in advanced airway management should be able to perform. Direct surgical access to the trachea should be made via the cricothyroid membrane unless there is severe trauma to that region. This involves removal of cricoid pressure, if applied, which makes placement of devices such as the laryngeal mask and Combitube more successful if they are to be used as temporary oxygenation sources. Tracheostomy in the emergency situation is very difficult and probably has no place in advanced airway management during resuscitation.

There are several methods of gaining access to the airway via the cricothyroid membrane, including needle and surgical cricothyroidotomy and blind stab techniques using specifically designed equipment. These methods are hazardous in the emergency situation and should be undertaken when there is no other option and the procedure is life saving. Any of the techniques should be performed only by trained and practised operators. Training is accomplished by the use of manikins, animal larynx specimens, such as those used in the advanced trauma and advanced paediatric life support courses (ATLS and APLS) and by cadaver and post-mortem teaching if these facilities are available.

**Needle cricothyroidotomy.** This technique, which is the surgical airway of choice for all children because of their small airway size, involves placing a needle and catheter through the cricothyroid membrane and ventilating via a catheter which is left in situ. The bigger the catheter the easier is ventilation. However, the technique is only suitable to buy time while a more definitive surgical airway is created. Ventilation is difficult using a self-inflating bag but is more successful when a high pressure source of oxygen is used with inflation intermittently applied by occluding an aperture in the ventilation tubing. Careful observation of chest movement is essential to avoid barotrauma, and for the technique to be safe there should always be a clear route through the larynx and mouth for expired gases to escape. Sufficient expiration through the narrow catheter is usually not
possible despite physical attempts to compress the chest.

**Surgical cricothyroidotomy.** This technique is gaining in popularity, particularly in the trauma setting, although documented evidence of its effectiveness in cardiopulmonary resuscitation is lacking. The procedure involves incision of the cricothyroid membrane under direct vision and insertion of an appropriately sized tracheal tube. Ventilation is highly effective and a secure airway is created.

While surgical cricothyroidotomy appears to be a simple technique, it is not without complications, with some studies reporting a total failure rate of up to 12%. Others, however, have reported a much lower failure rate and this may depend on the skill of the operator. Precautions that can be taken to reduce complications include limiting the lateral extent of any horizontal incision, incising the inferior part of the cricothyroid membrane in an attempt to avoid the cricothyroid arteries, and directing the scalpel blade away from the head to avoid vocal cord damage.

The technique is indicated in cases when life-threatening upper airway obstruction is present and all other attempts to secure the airway and ventilate the patient’s lungs have failed. Persistent attempts at tracheal intubation may result in worsening hypoxia and in these cases an early decision to create a surgical airway should be made. Because of the high complication rate significant training and experience are required.

**Blind stab techniques.** This method uses a single stab technique through the skin, subcutaneous tissues and cricothyroid membrane. Several commercially available kits (Portex, Cook Critical Care, Rusch) allow access to the airway using the technique. Most are simply large trocars over which a short, wide-bore tube is passed with a standard 22-mm connector. Some kits incorporate the use of guide wires and others use a more graded, dilational system.

Whichever product is used it is apparent that the technique may present considerable problems if it is not appropriately taught. Furthermore, access to the airway in the patient who is attempting to breath with a larynx that is constantly moving under the skin can be very difficult. Nevertheless, the concept of a readily available, rapid access device that does not require additional pieces of equipment for insertion is to be commended. Only by using and practising inserting such devices can appropriate experience be gained.

**ADVANCED MANAGEMENT OF VENTILATION**

Advanced ventilation methods are designed to overcome the shortcomings of expired air resuscitation techniques. However, if applied poorly they can be less effective and more hazardous than well executed basic techniques.

During cardiopulmonary resuscitation oxygenation is paramount; carbon dioxide delivery is likely to be low thus eliminating the requirements for large tidal volumes and lung compliance may be considerably reduced requiring higher inflation pressures.

There is some experimental evidence suggesting that ventilation itself may not be of paramount importance during the first few minutes after cardiac arrest. Indeed chest compression alone may generate sufficient tidal volumes for adequate oxygenation provided the airway is patent and a high inspired oxygen source is provided. This may be significant during the first few minutes after cardiac arrest, particularly if first responders are unwilling or unable to provide suitable ventilatory assistance.

Work in humans using active compression-decompression CPR has also demonstrated the potentially satisfactory tidal volumes generated by this technique alone, allowing sufficient ventilation to maintain blood-gas values at near normal levels provided the airway remains patent.

**Ventilation devices**

Devices for advanced management of ventilation include the self-inflating bag–valve–mask, anaesthesia systems, oxygen powered and automatic resuscitators and devices for transtracheal jet ventilation. These latter devices allow some ventilation via a cannula placed in the cricothyroid membrane, as described above. The system uses a high pressure oxygen source and a purpose designed injector. The method is relatively inefficient at eliminating carbon dioxide, although in cardiac arrest situations this may not be of much importance initially.

The self-inflating bag–valve devices are still the mainstay of ventilation for many during resuscitation. They are portable, robust and convenient but require considerable skill when used with a face mask, and a two-rescuer technique has therefore been recommended. The importance of generating large tidal volumes has now been questioned, however, and a single-rescuer technique may be appropriate with smaller lung volumes equally acceptable. Of greater importance is that oxygen is provided at or close to an $F_{O_2}$ of 1.0. This can only be achieved effectively by the use of large volume oxygen reservoir bags or the use of a demand valve.

Anaesthesia systems and manually triggered ventilators have a limited place in resuscitation as they are either in a fixed location or require the operator’s hands for providing ventilation, or both. Automatic ventilators, however, give the best all round option; they provide an $F_{O_2}$ of 1.0, consistent tidal volumes and ventilatory frequencies, and free the rescuer’s hands for other tasks. Many sophisticated models are now available which incorporate air–oxygen mix facilities, the ability to provide PEEP, disconnect alarms, variable I:E ratios and airway pressure monitoring facilities. They are compact, robust and lightweight and function under a variety of climactic and environmental conditions. The only drawback is the relatively large consumption of oxygen that may be used as the driving gas. This may cause problems when no piped gas is available and gas cylinders have to be used.

A flow chart for the advanced management of the airway and ventilation is shown in figure 5.
Acknowledgement

Figure 1–5 are adapted from the Guidelines for basic and advanced management of the airway and ventilation during resuscitation of the European Resuscitation Council and are reproduced with permission. Resuscitation 1996; 31: 187–230.

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