Section 3: Adjuncts for Oxygenation, Ventilation, and Airway Control

Oxygenation Devices

During cardiopulmonary emergencies use supplemental oxygen as soon as it is available. Rescue breathing (ventilation using exhaled air) will deliver approximately 16% to 17% inspired oxygen concentration to the patient, ideally producing an alveolar oxygen tension of 80 mm Hg. During cardiac arrest and CPR, tissue hypoxia occurs because of low cardiac output with reduced peripheral oxygen delivery and a resulting wide arteriovenous oxygen difference. Additional factors that cause hypoxia are intrapulmonary shunting with attendant ventilation-perfusion abnormalities and underlying respiratory disease. Tissue hypoxia leads to anaerobic metabolism and metabolic acidosis. Acid-base imbalance frequently blunts the beneficial effects of chemical and electrical therapy. For these reasons 100% inspired oxygen (FiO₂=1.0) is recommended during BLS and ACLS when available. High inspired oxygen tensions will tend to maximize arterial blood oxygen saturation and, in turn, systemic oxygen delivery (cardiac output × blood oxygen content). Short-term therapy with 100% oxygen is beneficial and not toxic. Oxygen toxicity occurs during prolonged therapy with a high FiO₂.

In patients with acute MI, supplemental oxygen reduces both the magnitude and the extent of ST-segment changes on the ECG. We recommend oxygen administered at 4 L/min by nasal cannula for the first 2 to 3 hours for all patients with suspected acute coronary syndromes (Class IIa). The use of oxygen beyond 3 to 6 hours is indicated for patients with continuing or recurrent ischemia, complicated infarcts with congestive heart failure, or arrhythmia until hypoxemia has resolved and the patient is clinically stable.

Ventilatory Devices

Masks

A well-fitting mask can be an effective, simple adjunct for use in artificial ventilation by appropriately trained rescuers. Masks should be made of transparent material to allow detection of regurgitation. They should be capable of a tight seal on the face, covering both mouth and nose. Masks should be fitted with an oxygen (insufflation) inlet and have a standard 15-/22-mm connector and should be available in one average size for adults with additional sizes for infants and children. For mouth-to-mask ventilation we recommend masks equipped with a 1-way valve that diverts the victim’s exhaled gas. Mouth-to-mask ventilation has been shown to be superior to that with bag-mask devices in delivering adequate tidal volumes on manikins. These devices are not to be confused with face-shield devices, which do not have an exhalation port. The efficacy of face shields has not been compared with that of other devices, and at this time face shields are recommended for BLS lay rescuers only (Class IIb). An adequate seal is best achieved with a mouth-to-mask device when the rescuer is positioned at the top of the patient’s head (Figure 1). The rescuer ventilates the victim by sealing his or her lips around the coupling adapter of the mask. Use both hands to hold the mask securely in position and maintain airway patency with head tilt. Manikin practice with masks should be required of all personnel who are likely to use a mask for mouth-to-mask ventilation.

Bag-Valve Devices

Bag-valve devices consist of a bag (self-inflating) and a valve (nonrebreathing). They may be used with a mask, a tracheal tube, or other alternative airway adjuncts. Most commercially available adult bag-mask units have a volume of approximately 1600 mL. This volume is much greater than currently recommended tidal volumes for CPR (10 mL/kg, 700 to 1000 mL). When the airway is unsecured (as with a mask versus a tracheal tube), the possibility of overventilation with gastric inflation, subsequent regurgitation, and aspiration becomes a significant concern. In several studies many rescuers were able to deliver adequate tidal volumes (6 to 7 mL/kg, approximately 500 mL) with a bag-valve and mask to intubated manikins (Class IIa). To optimize bag-valve and mask performance, one rescuer must be positioned at the top of the victim’s head. Generally an oral airway should be inserted (see below) and, if possible, the head elevated if no concern for neck injury exists. While the head is maintained in position, deliver the selected tidal volume (preferably 6 to 7 mL/kg) over 2 seconds. Slow, gentle ventilation minimizes risk of gastric inflation. A bag-valve device may be used with any airway adjunct, such as tracheal tube, laryngeal mask airway, or esophageal-tracheal Combitube. Proper use of these combinations requires training, practice, and demonstrated proficiency.

A satisfactory bag-valve unit should have (1) a self-refilling bag, (2) a nonjam valve system allowing for a maximum oxygen inflow rate of 30 L/min, (3) a no–pop-off valve, (4) standard 15-/22-mm fittings, (5) a system for delivering high concentrations of oxygen through an ancillary oxygen reservoir, (6) a true nonrebreathing valve, and (7) the capability to perform satisfactorily under all common environmental conditions and extremes of temperature (Figure 2).

Automatic Transport Ventilators

Automatic patient transport ventilators (ATVs) specifically designed for prehospital care and portability have been used in Europe since the early 1980s. Their acceptance in the...
Other devices used in prehospital care in intubated patients. Studies have observed improved lung inflation or absent gastric inflation when ATVs were compared with other devices, including mouth-to-mask, bag-mask, and manually triggered devices. This is due to the lower inspiratory flow and longer inspiratory times provided by ATVs.

Disadvantages of ATVs include the need for an oxygen source and electric power. In addition, some ATVs may be inappropriate for children under 5 years of age. Because most ATVs require either an oxygen source or an electric power source, a self-inflating bag-valve device or a simple mask should always be available in case the oxygen source is depleted, or no oxygen or electric power source is available, or the ventilator malfunctions.

ATVs used for prehospital care should be simple and time or volume-cycled. Avoid pressure-cycled devices. Delivered tidal volumes should be relatively unaffected by changes in lung-thorax impedance (<10% change). Operational gas consumption should be <5 L/min. ATVs should have the following minimum features:

- A lightweight connector with a standard 15-/22-mm coupling for a face mask, tracheal tube, or other airway adjunct
- A lightweight (<4 kg), compact, rugged design, with a carrying or mounting bracket
- Capability of operating under likely extremes of temperature
- A default peak inspiratory pressure limit of 60 cm H₂O, adjustable from 20 to 80 cm H₂O, that is easily accessible to the user
- An audible alarm that sounds when the peak inspiratory limiting pressure is generated. This alerts the rescuer that low compliance or high airway resistance is resulting in a diminished tidal volume delivery
- Minimal gas compression volume in the breathing circuit
- Ability to deliver an FiO₂ of 0.5 to 1.0
- A default inspiratory time of 2 seconds in adults and 1 second in children and default inspiratory flow of approximately 30 L/min in adults and 15 L/min in children, with the ability to adjust inspiratory time and flow once the patient is intubated with a tracheal tube or alternative airway
- A default rate of 10 breaths per minute for adults and 20 breaths per minute for children, with the ability to adjust the rate once the patient is intubated with a tracheal tube or alternative airway

A demand-flow valve may be incorporated into the ATV to reduce the work of breathing should spontaneous breathing time, ATVs are considered to provide advantages over alternative methods of ventilation:

- In intubated patients they free the rescuer for other tasks.
- In unintubated patients the rescuer has both hands free for mask application and airway maintenance.
- Cricoid pressure can be applied with one hand while the other seals the mask on the face.
- Once set, they provide a specific tidal volume, respiratory rate, and minute ventilation.

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- A lightweight connector with a standard 15-/22-mm coupling for a face mask, tracheal tube, or other airway adjunct
- A lightweight (<4 kg), compact, rugged design, with a carrying or mounting bracket
- Capability of operating under likely extremes of temperature
- A default peak inspiratory pressure limit of 60 cm H₂O, adjustable from 20 to 80 cm H₂O, that is easily accessible to the user
- An audible alarm that sounds when the peak inspiratory limiting pressure is generated. This alerts the rescuer that low compliance or high airway resistance is resulting in a diminished tidal volume delivery
- Minimal gas compression volume in the breathing circuit
- Ability to deliver an FiO₂ of 0.5 to 1.0
- A default inspiratory time of 2 seconds in adults and 1 second in children and default inspiratory flow of approximately 30 L/min in adults and 15 L/min in children, with the ability to adjust inspiratory time and flow once the patient is intubated with a tracheal tube or alternative airway
- A default rate of 10 breaths per minute for adults and 20 breaths per minute for children, with the ability to adjust the rate once the patient is intubated with a tracheal tube or alternative airway

A demand-flow valve may be incorporated into the ATV to reduce the work of breathing should spontaneous breathing
return. The valve should be able to deliver a peak inspiratory flow rate of at least 120 L/min (2 L/s) on demand. The pressure to trigger spontaneous flow should not exceed −2 cm H₂O.

Some ATVs allow higher preselected ventilator breathing rates. During CPR use caution in selecting ventilation rates more frequent than 10 per minute in adults or 20 per minute in children, because adequate time for exhalation is necessary to prevent air trapping and a positive end-expiratory pressure (auto-PEEP) effect. Auto-PEEP may reduce forward blood flow (ie, effective cardiac output) because pulmonary perfusion pressures are very low during CPR. Pulmonary capillary flow is easily impeded by high alveolar pressure. An appropriate exhalation time to maintain a 1:2 inhalation-to-exhalation time (I:E) ratio is necessary to minimize air trapping.¹⁷

Additional desirable features include a pressure manometer, provision for PEEP in more sophisticated ventilators, at least two controls (one for rate and one for tidal volume), and alarms to indicate depletion of oxygen cylinders, ventilator disconnect, or low battery.

Directors of prehospital or transport programs need to ensure that ATVs are used only by personnel who have received adequate ATV training. Monitoring of use and complication rates is essential to ensure safe and effective use of ATVs.

Oxygen-Powered, Manually Triggered Devices

Oxygen-powered, manually triggered devices have been used in prehospital care for >25 years despite a paucity of high-level scientific evidence supporting their use. When used with a face mask, high inspiratory flow and pressure may cause massive gastric inflation. When used with other airway adjuncts, high flow and pressure may cause barotrauma. In an effort to limit the damage caused by these devices, in 1986 a recommendation was made to limit flow to 40 L/min. Oxygen-powered manually triggered devices are not recommended at this time (Class Indeterminate). Further in vivo studies are needed to compare their efficacy with that of bag-valve devices and ATVs.
Airway Adjuncts

Oropharyngeal Airways

Oropharyngeal airways should be reserved for obtunded unconscious patients who are not intubated (Class IIa). Care is required in placement of the oral airway because incorrect insertion can displace the tongue into the hypopharynx and result in airway obstruction. In conscious patients oropharyngeal airways can promote retching, vomiting, or laryngospasm caused by activation of the gag reflex. Oral airways should be inserted only by persons trained adequately in their use. Oropharyngeal airways should be available in various infant, child, and adult sizes.

Nasopharyngeal Airways

Nasopharyngeal airways are especially useful in patients with trismus, biting, clenched jaws, or maxillofacial injuries, which prevent placement of an oral airway (Class IIa). They should be used with caution in patients with suspected fracture at the base of the skull. In patients who are not deeply unconscious, nasopharyngeal airways are better tolerated than oropharyngeal ones. Insertion can cause damage to the nasal mucosa, resulting in bleeding. If the tube is too long, it may stimulate the laryngeal or glossopharyngeal reflexes to produce laryngospasm, retching, or vomiting. As with all adjunctive equipment, safe use of nasopharyngeal airways requires adequate training, practice, and retraining.

Alternative Airways

In some communities tracheal intubation is not permitted, or patients are so few that practitioners obtain little experience. Alternative airways that require blind passage of the device into the airway may be simpler to master than passage of a tracheal tube under direct vision. Alternative airways include the laryngeal mask airway (LMA), the esophageal-tracheal Combitube (ETC), and the pharyngotracheal lumen airway (PTL). When used by adequately trained healthcare providers, the LMA and the ETC provide superior ventilation compared with face masks in patients in cardiac arrest (Class IIa). To achieve good outcomes with these devices, healthcare providers must maintain a high level of knowledge and skills through frequent practice and field use.

Esophageal-Tracheal Combitube

The ETC is an invasive double-lumen airway with 2 inflatable balloon cuffs that is inserted without visualization of the vocal cords. Assessment of the location of the distal orifice18 is then made, and the patient is ventilated through the appropriate opening. One lumen contains ventilating side holes at the hypopharyngeal level and is closed at the distal end; the other lumen has a distal open end with a cuff similar to a tracheal tube. When inflated the large pharyngeal balloon fills the space between the base of the tongue and the soft palate, anchoring the ETC into position, and isolates the oropharynx from the hypopharynx. The tube most commonly finds its way into the esophagus because of the stiffness and curve of the tube and the shape and structure of the pharynx. The tube is advanced until the patient’s teeth lie between 2 marks printed on the tube. The pharyngeal and distal balloons are then inflated, thus isolating the oropharynx above the upper balloon and the esophagus (or trachea) below the lower balloon.

The advantages of the ETC over the face mask are similar to those of the tracheal tube over the face mask: isolation of the airway, reduction in the risk of aspiration, and more reliable ventilation. The advantages of the ETC over the tracheal tube relate chiefly to ease of training and maintenance of placement skills, because laryngoscopy and visualization of the vocal cords are not necessary for insertion of the ETC. Ventilation and oxygenation with the ETC compare favorably with those achieved with the tracheal tube. Successful insertion rates with the ETC range from 69% to 100%.19–25 Because successful insertion is not ensured, providers should have a strategy for airway management when they are unable to ventilate with their first-choice adjunct. Fatal complications with the ETC may occur if the position of the distal lumen of the ETC in the esophagus or the trachea is identified incorrectly. In one EMS system a retrospective review reported that the incorrect port was used for ventilation in 3.5% of cases.20 For this reason use the ETC in conjunction with an end-tidal CO_2 or esophageal detector device.26,27

Another possible complication from the ETC is esophageal trauma.28 Eight cases of subcutaneous emphysema were retrieved from a retrospective review of 1139 patients resuscitated with the ETC by emergency medical technicians. Four patients underwent autopsy, and 2 were found to have esophageal lacerations.29 To optimize insertion rates and to minimize complications, providers should receive adequate initial training in use of the ETC and should practice with the device regularly. To ensure optimal outcomes, we also highly recommend that EMS and other healthcare providers monitor their success rates and the occurrence of complications.

Laryngeal Mask Airway

The LMA is an adjunctive airway device composed of a tube with a cuffed mask-like projection at the distal end (see Figure 3A).30 The LMA is introduced into the pharynx (Figure 3B) and advanced until resistance is felt as the distal portion of the tube locates in the hypopharynx. The cuff is then inflated, which seals the larynx, leaving the distal opening of the tube just above the glottis, providing a clear, secure airway (Figure 3C and 3D).

The LMA provides a more secure and reliable means of ventilation than the face mask.31,32 Although the LMA does not ensure absolute protection against aspiration, studies have shown that regurgitation is less likely with the LMA than with the bag-mask device and that aspiration is uncommon.33,34 In comparison with the tracheal tube, the LMA provides equivalent ventilation. Training in the placement and use of an LMA is simpler than tracheal intubation because laryngoscopy and visualization of the vocal cords are unnecessary for insertion of the LMA.35–37 The LMA may have advantages over the tracheal tube when access to the patient is limited,38 there is a possibility of unstable neck injury,39 or appropriate positioning of the patient for tracheal intubation is impossible.

Studies have examined the use of the LMA by nurses, respiratory therapists, and EMS personnel, many of whom...
had not previously used either an LMA or a tracheal tube. Successful insertion rates with the LMA range from 64% to 100%.25,34,40–44

Even when the LMA can be inserted, studies report that a small proportion of patients cannot be ventilated with the LMA. Because insertion and ventilation are not ensured, it is important for providers to have an alternative strategy for management of the airway. Providers should receive adequate initial training in the use of the LMA and should practice with the device regularly to optimize insertion rates and to minimize complications. To ensure optimal outcomes we also highly recommend that EMS and other healthcare providers monitor their success rates and the occurrence of complications.

**Transtracheal (Translaryngeal) Catheter Ventilation**

In those rare cases when airway obstruction is not relieved by any of the methods described above, additional procedures are necessary. These include transtracheal catheter or translaryngeal ventilation. Only specially trained and experienced personnel should attempt such procedures.

**Pharyngotracheal Lumen Airway**

The PTL is a double-lumen tube similar in structure and function to the ETC.45 The tube is inserted blindly into the pharynx, ending in either the esophagus or the trachea. Assessment of its location is then made, and the patient is ventilated through the proper lumen. In the only published

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**Figure 3.** Laryngeal mask airway. A, LMA is an adjunctive airway that consists of a tube with a cuffed mask-like projection at distal end. B, LMA is introduced through mouth into pharynx. C, Once LMA is in position, a clear, secure airway is present. D (Anatomic detail), During insertion, LMA is advanced until resistance is felt as distal portion of tube locates in hypopharynx. Cuff is then inflated. This seals larynx and leaves distal opening of tube just above glottis, providing a clear, secure airway (see arrow).
study since 1992 in which use of the PTL was examined, the tube performed well but was preferred less than the ETC.\textsuperscript{21} The PTL is not currently in wide use (Class Indeterminate).

**Cuffed Oropharyngeal Airway**

The cuffed oropharyngeal airway (COPA) was first described in 1992.\textsuperscript{46} Although designed originally for spontaneous ventilation in anesthetized subjects, it may represent a useful adjunct during resuscitation. The device is a modified oropharyngeal airway with a distal inflatable cuff and proximal standard 15-mm connector to which a self-inflating bag can be attached. Recent data suggests that the COPA is relatively easy to use and may offer an effective method of providing an adequate airway during resuscitation by personnel not trained in more advanced techniques.\textsuperscript{47}

**Tracheal Intubation**

In the absence of a protected airway, providing adequate lung inflations may require pharyngeal pressures sufficient to cause gastric inflation, subsequent regurgitation, and the potential for aspiration of gastric contents into the lungs.\textsuperscript{48–51} In extreme cases, gastric inflation may elevate the diaphragm sufficiently to interfere with lung inflation.\textsuperscript{52,53} Therefore, as soon as practical during the resuscitative process, trained personnel should intubate the trachea or insert an alternative airway (LMA or ETC).

Tracheal intubation should be preceded by preoxygenation of the patient. If the patient is ventilating spontaneously, preoxygenation is achieved by providing 3 minutes of high-flow oxygen. If spontaneous ventilation is insufficient, assist ventilation with a bag-mask device.\textsuperscript{54}

Currently the tracheal tube is considered the ventilation adjunct of choice because it keeps the airway patent, permits suctioning of airway secretions, ensures delivery of a high concentration of oxygen, provides a route for the administration of certain drugs, facilitates delivery of a selected tidal volume, and protects the airway from aspiration of gastric contents or blood and mucus from the oropharynx.\textsuperscript{55} Repeated safe and effective placement of the tracheal tube, over the wide range of patient and environmental conditions encountered in resuscitation, requires considerable skill and experience. Unless initial training is sufficient and ongoing practice and experience are adequate, fatal complications may result.

Multiple or unsuccessful intubation attempts may affect outcome from cardiac arrest adversely. Rates for failure to intubate are as high as 50\% in EMS systems with a low patient volume and providers who do not perform intubation frequently.\textsuperscript{56,57} When tracheal intubation is attempted by providers with insufficient skill, the following complications may be seen: trauma to the oropharynx, ventilation withheld for unacceptably long periods, delayed or withheld chest compressions, esophageal or bronchial intubation, failure to secure the tube, and failure to recognize misplacement of the tube. Therefore, inexperienced providers should use only those airway management devices for which they have been adequately trained. Those who perform tracheal intubation require either frequent experience or frequent retraining. EMS systems should keep a record for each provider, documenting the number of intubations performed and success rates and complications (Class IIa).

Indications for tracheal intubation include (1) inability of the rescuer to ventilate the unconscious patient with less invasive methods and (2) absence of protective reflexes (coma or cardiac arrest).

During the process of tracheal intubation, the maximum interruption to ventilation should be 30 seconds. If more than 1 attempt at intubation is required, adequate ventilation and oxygenation must be provided between attempts. If the patient has a perfusing rhythm, use pulse oximetry and ECG monitoring continuously during intubation attempts.

Whenever possible a second rescuer should apply cricoid pressure during tracheal intubation in adults to protect against regurgitation of gastric contents and to help ensure tube placement in the tracheal orifice. Apply pressure with the thumb and index fingers to the right and left anterolateral aspects of the cricoid cartilage just lateral to the midline. Avoid overzealous pressure; it will occlude the airway and impair tracheal intubation.\textsuperscript{58,59} Maintain cricoid pressure until the cuff of the tracheal tube is inflated.\textsuperscript{46,60,61} The BURP (Backward, Upward, Rightward Pressure) technique may be useful in bringing the vocal cords into the field of vision of the intubator.

Tracheal tubes should be available in a variety of sizes. They should have standard 15-/22-mm connectors and should have high-volume, low-pressure cuffs suitable for adults and older children. The size of tracheal tube required typically is 8 mm for average adult women and 8 mm for average adult men. Because of the variation in size of adults, a range of tubes should be available.

A stylet should be available and may be used to assist with tracheal tube insertion by providing some stiffness to the tube and by allowing the direction of the tube to be controlled better during manipulation. When used, the stylet should not extend beyond the distal end of the tube.

Another excellent device to assist with placement of the tracheal tube is the gum elastic bougie. Because of its size and flexibility, the bougie is easier to place in the trachea than a tracheal tube. Once the bougie is placed in the trachea, the tracheal tube is passed over the bougie and into position in the trachea.\textsuperscript{62–66}

Difficulties in achieving tracheal intubation usually occur because of inability to bring the vocal cords into view through the laryngoscope. Visualization is best accomplished by flexing the neck and extending the head at the atlanto-occipital joint (the “sniffing position”). Once the vocal cords are seen, the tube should be placed so that the cuff is just beyond the cords. In the average adult this position usually results in the tube lying at a depth marked on the side of the tube between the 19- and 23-cm marks at the front teeth. The cuff is then inflated with just enough air to occlude the airway (usually 10 mL). An adequate seal is confirmed by listening over the larynx while ventilation is continued and air is added to the cuff. While
a normal tidal volume is delivered, air is added to the cuff just until the audible air leak around the tube disappears.

Immediately after insertion of the tracheal tube, confirm placement by auscultating over the epigastrium, the midaxillary, and the anterior chest line on the right and left sides of the chest. Even when the tracheal tube is seen to pass through the vocal cords and is verified in the trachea by auscultation, make secondary confirmation of placement with an end-tidal CO$_2$ or esophageal detection device (Class IIa). Extensive data shows that clinical signs of proper tube placement (such as condensation in the tube, auscultation over the lungs and abdomen, and chest rise) are not always reliable indicators of correct tube placement.

To protect against unrecognized esophageal intubation, confirmation of tube placement by an expired CO$_2$ or esophageal detection device is necessary. In the out-of-hospital setting, unrecognized misplacement of the tracheal tube has been reported in as many as 17% of patients. Once the tube is placed, especially out of hospital, the location of the tracheal tube must be monitored closely.

The esophageal detector device depends on the ability to aspirate air from the lower airways through a tracheal tube placed in the cartilage-supported rigid trachea. When the tube is in the esophagus, air cannot be aspirated because the esophagus collapses when aspiration is attempted. The esophageal detector device is generally reliable in patients with both a perfusing and a nonperfusing rhythm (Class IIa), but it may yield misleading results in patients with morbid obesity, late pregnancy, or status asthmaticus or when there are copious tracheal secretions. With some of these conditions, the trachea tends to collapse. In the case of status asthmaticus, the airway secretions or the small-airway obstruction that characterizes severe asthma blocks air aspiration from the lower airways.

**How to Confirm Accurate Placement of Tracheal Tube: Primary Confirmation**

Confirm tube placement immediately, assessing the first breath delivered by the bag-valve unit.

- As the bag is squeezed, listen over the epigastrium and observe the chest wall for movement. If you hear stomach gurgling and see no chest wall expansion, you have intubated the esophagus. Deliver no further ventilations. Remove the tracheal tube at once.
- Reattempt intubation after reoxygenating the victim (15 to 30 seconds of bag ventilations using 100% oxygen).
- If the chest wall rises appropriately and stomach gurgling is not heard, listen to the lung fields: left and right anterior, left and right midaxillary, and once again over the stomach. Document in the medical records where you heard breath sounds. If you have any doubt, stop ventilations through the tube.
- If there is continued doubt about correct tube placement, use the laryngoscope and look directly to see whether the tube is passing through the vocal cords.
- If the tube seems to be in place, reconfirm the tube mark at the front teeth (this was noted after the tube was inserted 1 to 2 cm past the vocal cords.
- Secure the tube with a purpose-built commercial device, although most traditional taping patterns are acceptable.
- Once the tube is secured, insert an oropharyngeal airway or add a bite block, or both, to prevent the patient from biting down and occluding the airway.

**How to Confirm Accurate Placement of Tracheal Tube: Secondary Confirmation**

A variety of electronic and mechanical devices, ranging from simple and inexpensive to complex and costly, are available for both in-hospital and out-of-hospital use. These include several models of end-tidal CO$_2$ detectors (qualitative, quantitative, and continuous) and a variety of esophageal detector devices.

**End-Tidal CO$_2$ Detectors**

Several commercial devices measure the concentration of exhaled CO$_2$ from the lungs. The presence of exhaled CO$_2$ indicates proper tracheal tube placement. A lack of CO$_2$ on the detector generally means that the tube is in the esophagus, particularly in patients with spontaneous circulation.

False-positive readings (tube is really in the trachea; device indicates in the esophagus; leads to unnecessary tube removal) may occur because CO$_2$ delivery is low in cardiac arrest patients with low blood flow to the lungs or in patients with a large amount of dead space (eg, significant pulmonary embolus). False-negative readings (tube is really in the esophagus; device indicates in the trachea) have been reported from patients who had ingested carbonated liquids before the arrest.

Continuous (usually quantitative as well) end-tidal CO$_2$ monitors can confirm successful tracheal tube placement within seconds of an intubation attempt. These monitors can also detect subsequent tracheal tube dislodgment, an event that is more likely to occur during out-of-hospital transportation of a patient.

**Esophageal Detector Devices**

These devices create a suction force at the tracheal end of the tracheal tube, either from pulling back the plunger on a large syringe or compressing a flexible bulb. If the tube is in the esophagus, the suction will pull the esophageal mucosa against the distal end of the detector and prevent movement of the device plunger or reexpansion of the suction bulb.

Expired CO$_2$ detectors are very reliable in patients with perfusing rhythms and are recommended to confirm tube position in these patients (Class IIa). During cardiac arrest, pulmonary blood flow may be so low that there is insufficient expired CO$_2$ so a correctly placed tracheal tube is not identified by the expired CO$_2$ detector. When expired CO$_2$ is detected in cardiac arrest, it is a reliable indicator of tube position, but when it is absent, we recommend adding a second method of confirming tracheal tube placement, such as the esophageal detector device (Class IIb).

*The use of the terms “false-positive” and “false-negative” when applied to a diagnostic technique can be confusing. The meanings can flip-flop depending on whether the esophageal detector device is “positive” when it detects proper tracheal tube placement, or “positive” when it detects esophageal placement. There is no widely accepted convention in discussing such tools. See the editorial on the carotid pulse check as a diagnostic test.—Editors*
A variety of electronic as well as simple, inexpensive, colorimetric detectors that detect exhaled CO\textsubscript{2} are available for both in-hospital and out-of-hospital use.

After you confirm the position of the tube in the trachea, careful auscultation is needed to avoid inadvertent right main bronchial intubation. Once you achieve the correct positioning of the tube, record the depth of the tube as marked at the front teeth and secure the tube. Once the tube is secured, place an oropharyngeal airway or bite block. The respiratory rate during cardiac or respiratory arrest when the patient has been intubated should be 12 to 15 breaths per minute (1 breath every 4 to 5 seconds). Once a tracheal tube is in place, ventilation need not be synchronized with chest compressions. Once spontaneous circulation is restored after cardiac arrest, continue to provide 12 to 15 breaths per minute.

After tube confirmation and fixation, obtain a chest x-ray to confirm proper position of the end of the tracheal tube above the carina.

In patients with severe obstructive pulmonary disease with increased resistance to exhalation, care should be taken not to induce air trapping, which may result in auto-PEEP. In patients with hypovolemia this may cause a profound reduction in blood pressure. Lower respiratory rates (6 to 8 per minute) should be used, allowing more time for complete exhalation of gas.

**Suction Devices**

Both portable and installed suction equipment should be available for resuscitative emergencies. The portable unit should provide vacuum and flow adequate for pharyngeal suction. It should be fitted with large-bore, nonkinking suction tubing and semiflexible pharyngeal tips. Several sterile suction catheters of various sizes should be available for suctioning through tracheostomy tubes, along with a non-breakable collection bottle and a supply of sterile water for cleaning tubes and catheters.

The installed suction unit should be powerful enough to provide an airflow of >40 L/min at the end of the delivery tube and a vacuum of >300 mm Hg when the tube is clamped. The amount of suction should be adjustable for use in children and intubated patients. Hand-powered suction units lack the problems associated with electric pumps and have had considerable anecdotal clinical success, although no formal evaluations have been published.

An additional set of rigid pharyngeal suction tips (tonsil suction tips) and sterile, curved tracheal suction catheters of various sizes should be available. For tracheal suction, a Y-piece or T-piece or a lateral opening should lie between the suction tube and the source of the on-off suction control. The suction yoke, collection bottle, water for rinsing, and suction tube should be readily accessible to the attendant in charge of the airway. Suction apparatus must be designed for easy cleaning and subsequent decontamination.

**Airway Summary**

Airway control using an invasive airway device is fundamental to ACLS. Determining rapidly whether the tracheal tube is in the esophagus or trachea should be one of the primary end points of training and clinical use of invasive airway techniques. This key skill is required for the safe and effective use of these devices. Training, frequency of use, and monitoring of success and complications influence the long-term impact of any device more than the choice of the specific device.

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