Airway Management

Devices to Provide Supplementary Oxygen

Overview

Oxygen administration is always appropriate for patients with acute cardiac disease or pulmonary distress. Various devices can deliver supplementary oxygen from 21% to 100% (Table 1).This section describes 4 devices to provide supplementary oxygen:

- Oxygen supply (cylinder or wall unit)
- Nasal cannula
- Face mask
- Venturi mask

Whenever you care for a patient receiving supplementary oxygen, quickly verify proper function of the oxygen delivery system in use.

Table 1. Delivery of Supplementary Oxygen: Flow Rates and Percentage of Oxygen Delivered.

Device	Flow Rates	Delivered O_2*
Nasal cannula	1 L/min	21%-24%
	2 L/min	25%-28%
	3 L/min	29%-32%
	4 L/min	33%-36%
	5 L/min	37%-40%
	6 L/min	41%-44%
Simple oxygen face mask	6-10 L/min	35%-60%
Face mask with O_2 reservoir (nonrebreathing mask)	6 L/min	60%
	7 L/min	70%
	8 L/min	80%
	9 L/min	90%
	10-15 L/min	95%-100%
Venturi mask	4-8 L/min	24%-40%
	10-12 L/min	40%-50%

*Percentage is approximate.

Oxygen Supply

"Oxygen supply" refers to an oxygen cylinder or wall unit that connects to an administration device to deliver oxygen to the patient. When the patient is receiving oxygen from one of these systems, be sure to check the following equipment:

- Valve handles to open the cylinder, pressure gauge, and flow meter
- Tubing connecting the oxygen supply to the patient's oxygen administration device

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Nasal Cannula

The nasal cannula (Figure 1) is a low-flow oxygen administration system designed to add oxygen to room air when the patient inspires.

- A nasal cannula provides up to 44% oxygen.
- In this low-flow system, inspired air mixes with room air. The ultimate inspired oxygen concentration is determined by the oxygen flow rate through the cannula and how deeply the patient breathes (tidal volume).
- Increasing the oxygen flow by 1 L/min (starting with 1 L/min) will increase the inspired oxygen concentration by approximately 4%:
  - 1 L/min: 21% to 24%
  - 2 L/min: 25% to 28%
  - 3 L/min: 29% to 32%
  - 4 L/min: 33% to 36%
  - 5 L/min: 37% to 40%
  - 6 L/min: 41% to 44%

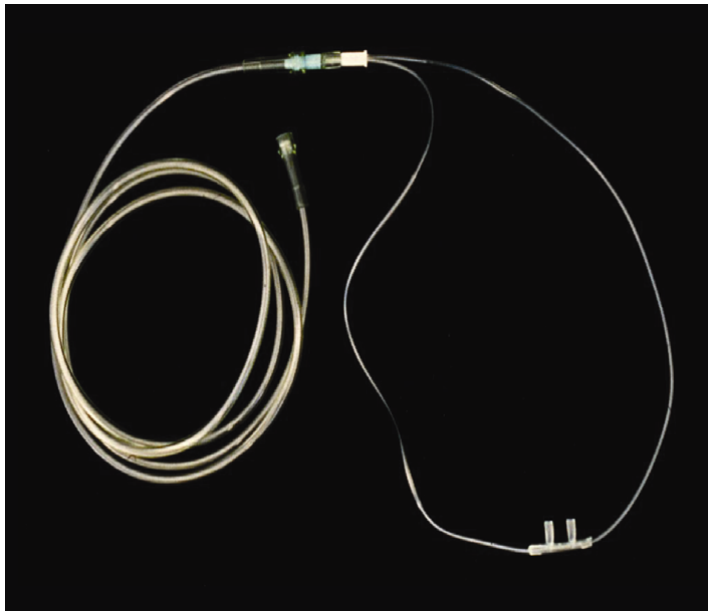


Figure 1. A nasal cannula used for supplementary oxygen delivery in spontaneously breathing patients.

Face Mask

A simple face mask delivers low oxygen flow to the patient's nose and mouth. A partial rebreathing mask consists of a face mask with an attached reservoir bag (Figure 2.)

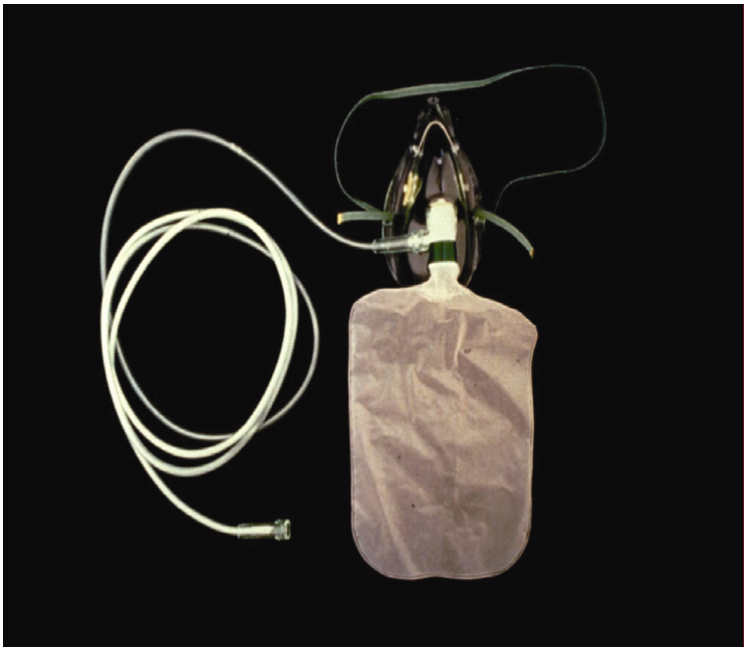


Figure 2. A face mask with oxygen reservoir used for supplementary oxygen delivery in spontaneously breathing patients.

A face mask can supply up to 60% oxygen with flow rates of 6 to 10 L/min (Table 1). A face mask with oxygen reservoir (nonrebreathing mask) provides up to 90% to 100% oxygen with flow rates of 9 to 15 L/min. In this system a constant flow of oxygen enters an attached reservoir.

Use a face mask with a reservoir for patients who

- Are seriously ill, responsive, and have adequate ventilation but require high oxygen concentrations
- May avoid endotracheal intubation if acute interventions produce a rapid clinical effect (eg, patients with acute pulmonary edema, chronic obstructive pulmonary disease [COPD], or severe asthma)
- Have relative indications for endotracheal intubation but maintain an intact gag reflex
- Have relative indications for intubation but have clenched teeth or other physical barriers to immediate intubation

The above patients may have a diminished level of consciousness and may be at risk for nausea and vomiting. A tight-fitting mask always requires close monitoring. Suctioning devices should be immediately available.

Venturi Mask

A Venturi mask enables a more reliable and controlled delivery of oxygen concentrations from 24% to 50%. Use the Venturi mask for patients who retain carbon dioxide (CO_2). Patients who have chronic high levels of CO_2 in

their blood and moderate-to-severe hypoxemia may develop respiratory depression if the drive stimulating them to breathe (oxygen) is reduced.

- A Venturi mask can accurately control the inspired oxygen concentration. Use this mask in patients with COPD, who usually have chronic hypercarbia (high CO_2) and mild to moderate hypoxemia.
- Administration of high oxygen concentrations to patients with end-stage COPD may produce respiratory depression because the increase in Pa_{O_2} eliminates the stimulant effect of hypoxemia on the respiratory centers.
- Never withhold oxygen from patients who have respiratory distress and severe hypoxemia simply because you suspect a hypoxic ventilatory drive. If oxygen administration depresses ventilation, support ventilation.

Delivered oxygen concentrations can be adjusted to 24%, 28%, 35%, and 40% using a flow rate of 4-8 L/min and 40% to 50% using a flow rate of 10-12 L/min. Observe the patient closely for respiratory depression. Use a pulse oximeter to quickly titrate to the preferred level of oxygen administration.

Bag-Mask Ventilation

Overview

The bag-mask device, which typically consists of a self-inflating bag and a nonrebreathing valve, may be used with a face mask or an advanced airway (Figure 3). Bag-mask ventilation is a challenging skill that requires considerable practice for competency. Providers can provide bag-mask ventilation with room air or oxygen if they use a self-inflating bag. This device provides positive-pressure ventilation when used without an advanced airway and therefore may produce gastric inflation and its complications.

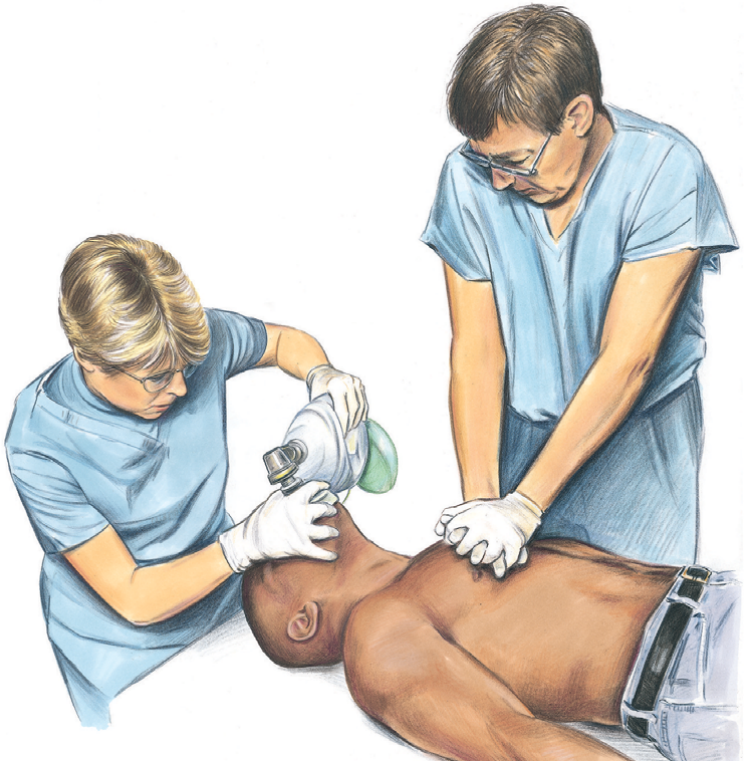


Figure 3. Bag-mask device with 2-rescuer CPR.

Use With an Advanced Airway

Advanced airway devices such as the laryngeal mask airway (LMA) and esophageal-tracheal Combitube are currently within the scope of EMS providers in several regions (with specific authorization from medical control). These devices are acceptable alternatives to bag-mask devices when used by healthcare providers who are well trained and have sufficient experience to use them. It is not clear that these devices are any more or less complicated to use than a pocket mask; training is needed for safe and effective use of both a bag-mask device and each of the advanced airways.

Tips for Performing Bag-Mask Ventilation

- Insert an oropharyngeal airway (OPA) as soon as possible if the patient has no cough or gag reflex to help maintain the airway.
- There is no specific tidal volume recommended for adults. Instead the tidal volume should be sufficient to achieve visible chest rise.
- Many healthcare providers cannot create a leakproof seal between the mask and face using 1 hand. The hand holding the mask must perform 2 tasks simultaneously: perform a head tilt and press the mask against the face while lifting the jaw. Perform and maintain a head tilt, and then use the thumb and index finger to make a “C,” pressing the edges of the mask to the face. Next use the remaining fingers to lift the angle of the jaw and open the airway (Figure 4A).
- For these reasons many experts recommend that 2 well-trained, experienced healthcare providers work together during bag-mask

ventilation. One provider should hold the mask with 2 hands, creating a leakproof seal between the mask and the face while lifting the patient's jaw. The second provider squeezes the bag slowly and gently over 1 second per ventilation (Figure 4B).

- These seal and volume problems do not occur when the bag-mask device is attached to the end of an advanced airway device (eg, endotracheal tube [ETT], Combitube, or LMA).

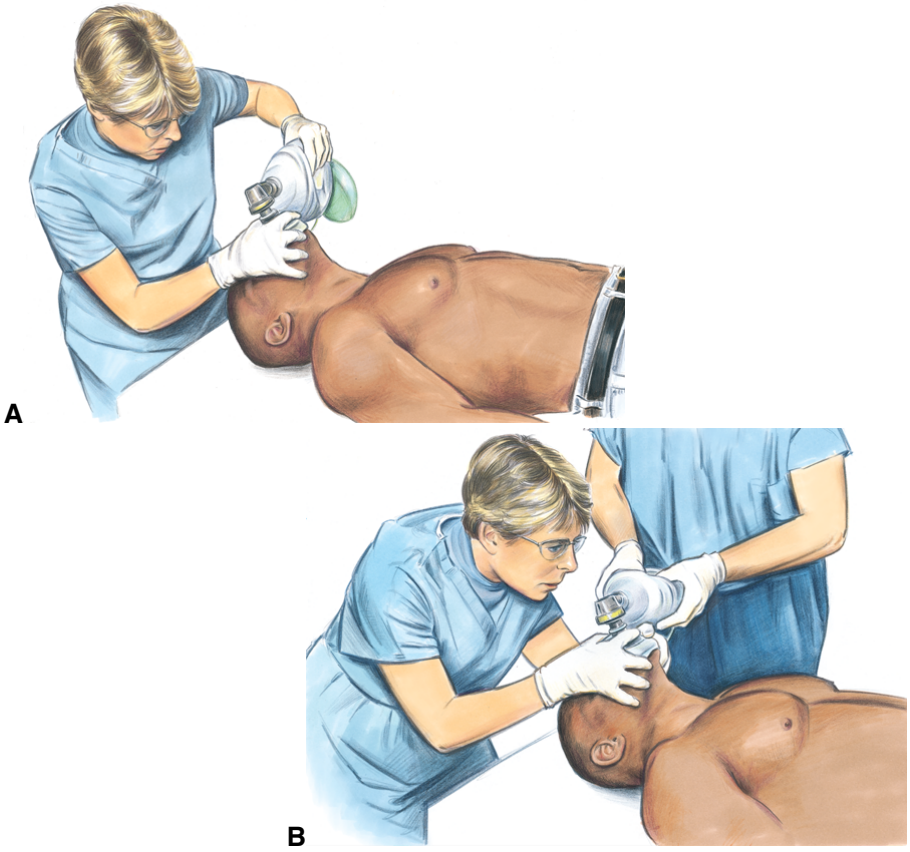


Figure 4. A, Mouth-to-mask E-C clamp technique of holding mask while lifting the jaw. Position yourself at the patient's head. Circle the thumb and first finger around the top of the mask (forming a "C") while using the third, fourth, and fifth fingers (forming an "E") to lift the jaw. **B,** Two-rescuer use of the bag mask. The rescuer at the patient's head tilts the patient's head and seals the mask against the patient's face with the thumb and first finger of each hand creating a "C" to provide a complete seal around the edges of the mask. The rescuer uses the remaining 3 fingers (the "E") to lift the jaw (this holds the airway open). The second rescuer slowly squeezes the bag (over 1 second) until the chest rises. Both rescuers should observe chest rise.

Ventilation With an Advanced Airway and Chest Compressions

When the patient has an advanced airway in place during CPR, 2 rescuers no longer deliver cycles of CPR (ie, compressions interrupted by pauses for ventilation).

- Chest compressions are delivered at a rate of 100 per minute.
- The provider delivering ventilations delivers 1 ventilation every 6 to 8 seconds (8 to 10 per minute).
- Providers should switch roles every 2 minutes to prevent compressor fatigue and deterioration in the quality and rate of chest compressions.
- Minimize interruptions in chest compressions.
- Avoid excessive ventilation (too many breaths or too large a volume).

Advanced Airway Adjuncts: Combitube

Overview

The Combitube (Figure 5) is an advanced airway that is an acceptable alternative to the use of an ETT. The Combitube is an invasive airway device with 2 inflatable balloon cuffs. It is inserted without visualization of the vocal cords. The tube is more likely to enter the esophagus than the trachea. When the tube does enter the esophagus, ventilation occurs through side openings adjacent to the vocal cords and trachea. If the tube enters the trachea, ventilation can still occur by an opening in the end of the tube.

Studies show that healthcare providers with all levels of experience can insert the Combitube and deliver ventilation comparable to that achieved with endotracheal intubation. The advantages of the Combitube are chiefly those related to ease of training. But only providers trained and experienced with the use of the Combitube should insert the device because fatal complications are possible.

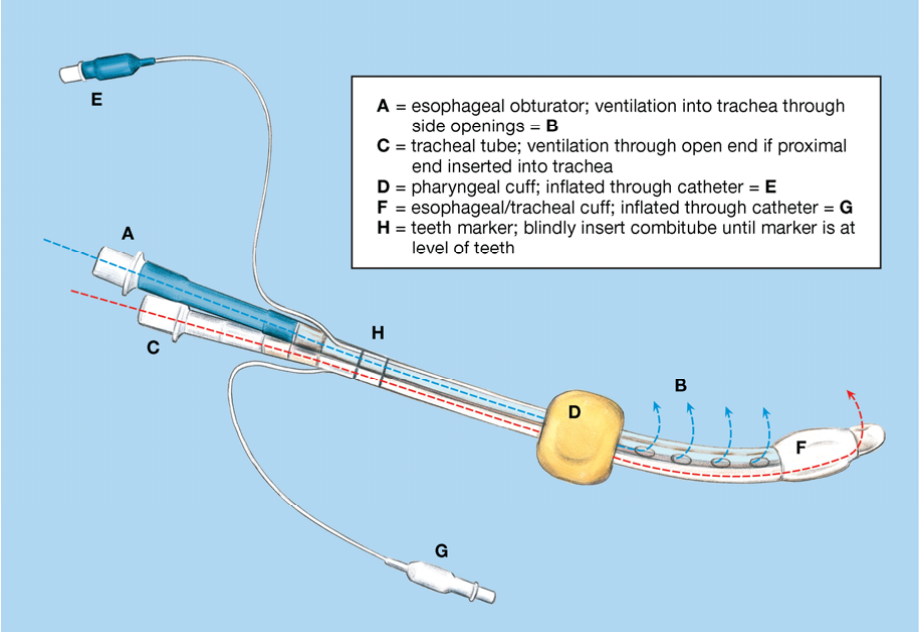


Figure 5. Esophageal-tracheal Combitube

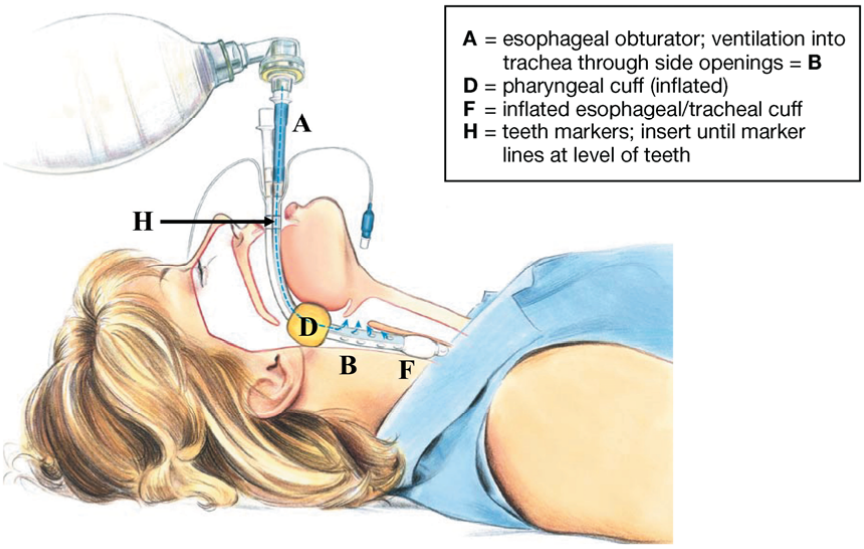


Figure 6. Esophageal-tracheal Combitube inserted in esophagus.

Insertion of the Combitube

The steps for blind insertion of the Combitube are as follows:

Step	Action
1	*Equipment preparation:* Check the integrity of both cuffs according to the manufacturer's instructions and lubricate the tube.
2	*Patient preparation:* Provide oxygenation and ventilation, sedate as clinically indicated, and position the patient. Rule out the following contraindications to insertion of the Combitube (according to the manufacturer's instructions): • Age younger than 16 years or height less than manufacturer's recommendation for adult and small adult sizes. • Gag reflex present • Known or suspected esophageal disease • Ingestion of a caustic substance

3	*Insertion technique:* • Hold the device with cuffs deflated so that the curvature of the tube matches the curvature of the pharynx. • Lift the jaw and insert the tube gently until the black lines on the tube (Figure 5 H) are positioned between the patient's teeth. (Do not force, and do not attempt for more than 30 seconds.) • Inflate the proximal/pharyngeal (blue) cuff with 100 mL of air. (Inflate with 85 mL for the smaller Combitube.) Then inflate the distal (white or clear) cuff with 15 mL of air. (Inflate with 12 mL for the smaller Combitube.)
4	Confirm tube location and select the lumen for ventilation. To select the appropriate lumen to use for ventilation, you must determine where the tip of the tube is located. The tip of the tube can rest in either the esophagus or the trachea. • *Esophageal placement:* Breath sounds should be present bilaterally with no epigastric sounds. Provide ventilation through the blue (proximal/pharyngeal) lumen. This action delivers ventilation through the pharyngeal side holes between the 2 cuffs, and air will enter the trachea. Because the tip of the tube rests in the esophagus, do not use the distal (white or clear) tube for ventilation. The distal cuff will also lie within the esophagus; inflation of this cuff prevents the ventilations that you deliver through the pharyngeal tube from entering the esophagus. • *Tracheal placement:* Breath sounds are absent and epigastric sounds are present when you attempt to provide ventilation through the blue (proximal/pharyngeal) lumen. Immediately stop providing ventilations through the blue lumen and provide them through the distal (white or clear) lumen that opens at the tip of the tube in the trachea. With endotracheal placement of the tube, the distal cuff performs the same function as a cuff on an ETT. Detection of exhaled CO_2 (through the ventilating white or clear lumen) should be used for confirmation, particularly if the patient has a perfusing rhythm. • *Unknown placement:* Breath sounds and epigastric sounds are absent. Deflate both cuffs and withdraw the tube slightly, reinflate the blue cuff, and then reinflate the white (or clear) cuff (see steps above). If breath sounds and epigastric sounds are still absent, remove the tube.
5	Insert a bite-block, provide ventilation, and continue to monitor the patient's condition and the position of the Combitube. A bite-block reduces the possibility of airway obstruction and tube damage. Keep the bite-block in place until you remove the Combitube.

Advanced Airway Adjuncts: Laryngeal Mask Airway

Overview

The LMA (Figure 7) is an advanced airway device that is considered an acceptable alternative to the ETT. The LMA is composed of a tube with a cuffed mask-like projection at the end of the tube.

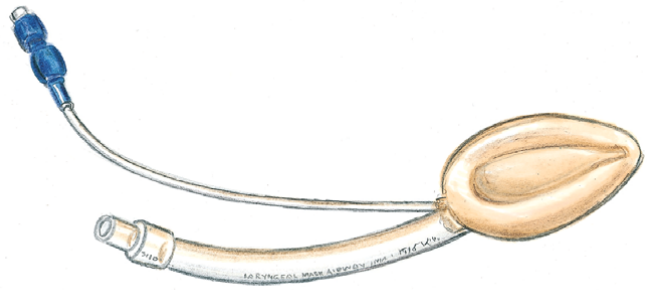
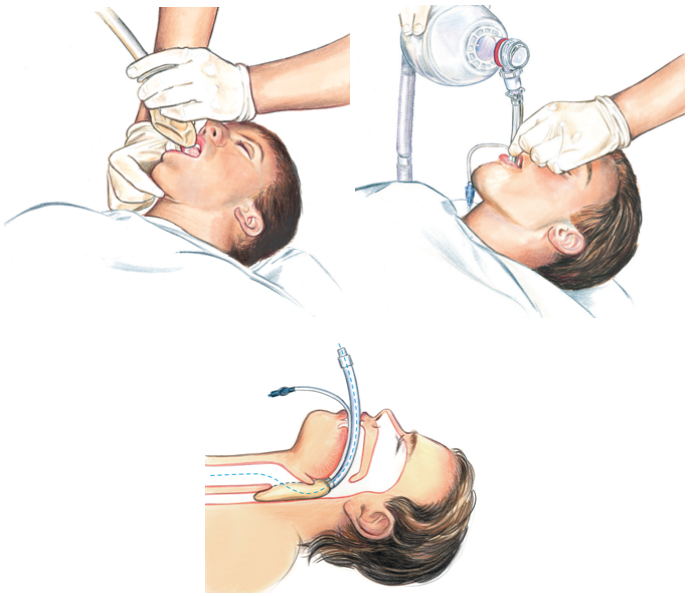


Figure 7. Laryngeal mask airway (LMA).

Insertion of the Laryngeal Mask Airway

The steps for blind insertion of the LMA (Figure 8) are as follows:

Step	Action
1	*Equipment preparation:* Check the integrity of the mask and tube according to the manufacturer's instructions. Lubricate only the posterior surface of the cuff to avoid blocking the airway aperture.
2	*Patient preparation:* Provide oxygenation and ventilation, sedate as indicated, and position the patient. Note that use of the LMA poses risks of regurgitation and aspiration in unresponsive patients. You must weigh these risks against the benefit of establishing an airway using this specific device.

3	*Insertion technique (Figure 8):* • Introduce the LMA into the pharynx and advance it blindly until you feel resistance. Resistance indicates that the distal end of the tube has reached the hypopharynx. • Inflate the cuff of the mask. Cuff inflation pushes the mask up against the tracheal opening, allowing air to flow through the tube and into the trachea. • Ventilation through the tube is ultimately delivered to the opening in the center of the mask and into the trachea. • To avoid trauma, do not use force at any time during insertion of the LMA. • Never overinflate the cuff after inflation. Excessive intracuff pressure can result in misplacement of the device. It also can cause pharyngolaryngeal injury (eg, sore throat, dysphagia, or nerve injury).
4	Insert a bite-block, provide ventilation, and continue to monitor the patient's condition and the position of the LMA. A bite-block reduces the possibility of airway obstruction and tube damage. Keep the bite-block in place until you remove the LMA.  **Figure 8.** Insertion of the laryngeal mask airway (LMA).

Endotracheal Intubation

Overview

Placement of an endotracheal tube (ETT), or endotracheal intubation, provides advanced airway management. The ETT

- Keeps the airway patent
- Enables delivery of a high concentration of oxygen
- facilitates delivery of a selected tidal volume to maintain adequate lung inflation
- May protect the airway from aspiration of stomach contents or other substances in the mouth, throat, or upper airway
- Permits effective suctioning of the trachea
- Provides an alternative route for administration of resuscitation medications when intravenous (IV) or intraosseous (IO) access cannot be obtained. These medications are atropine, vasopressin, epinephrine, and lidocaine.. Note however that drug delivery and drug effects following endotracheal administration are less predictable than those delivered by the IV/IO route.

The Combitube and LMA are now considered acceptable alternatives to the ETT for advanced airway management.

Misplacement of an ETT can result in severe, even fatal, complications. For this reason only skilled, experienced personnel should perform endotracheal intubation. In most states medical practice acts specify the level of personnel allowed to perform this procedure. For clinical reasons intubation should be restricted to healthcare providers who meet the following criteria:

- Personnel are well trained.
- Personnel perform intubation frequently.
- Personnel receive frequent refresher training in this skill.
- ETT placement is included in the scope of practice defined by governmental regulations.

and

- Personnel participate in a process of continuous quality improvement to detect frequency of complications and minimize those complications.

Placement of an ETT is an important part of a resuscitation attempt. But it is a much lower priority than providing high-quality continuous chest compressions with few interruptions, delivering defibrillation as needed and establishing IV/IO access.

Technique of Endotracheal Intubation

Many ACLS providers do not perform intubation because of the professional restrictions noted above. Nonetheless, all members of the resuscitation team must understand the concept of endotracheal intubation and the steps involved. Team members may assist with endotracheal intubation and must know how to integrate compressions and ventilations when an ETT is placed. This knowledge is often more important than knowing how to perform the procedure itself.

All ACLS providers must understand the following:

- When to intubate
- How to confirm successful tube placement
- How to integrate chest compressions and ventilations
- How to prevent and recognize tube dislodgment
- How to verify and monitor effective oxygenation and ventilation

Indications for Endotracheal Intubation

- Cardiac arrest when bag-mask ventilation is not possible or is ineffective
- Responsive patient in respiratory compromise is unable to oxygenate adequately despite noninvasive ventilatory measures
- Patient is unable to protect airway (eg, coma, areflexia, or cardiac arrest)

Cricoid Pressure Maneuver

During endotracheal intubation *in adults receiving CPR,* a third healthcare provider not involved in compressions or ventilations should apply cricoid pressure (Figure 9). This maneuver may protect against regurgitation of gastric contents and helps ensure tube placement in the tracheal orifice. This provider should maintain cricoid pressure until the ETT is inserted, the cuff of the ETT is inflated, and proper tube position is confirmed.

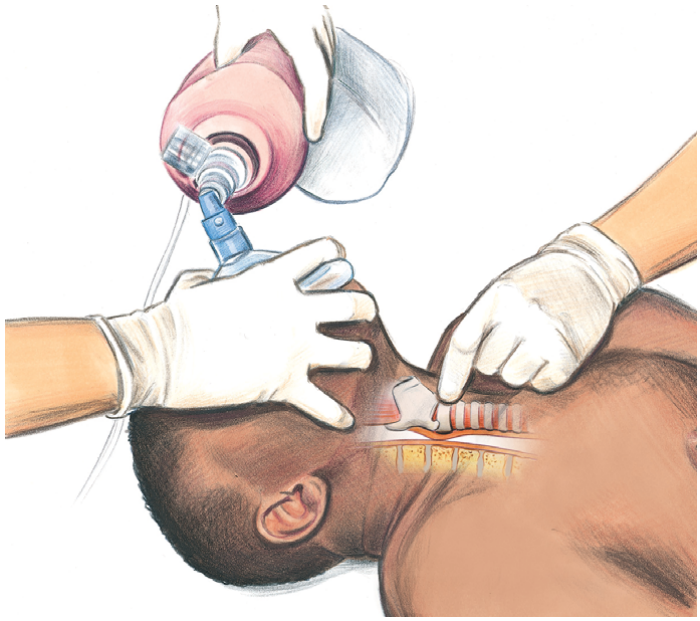


Figure 9. Cricoid pressure.

The steps of the cricoid pressure maneuver are as follows:

Step	Action
1	Find the prominent thyroid cartilage (Adam's apple).
2	Find the soft depression below the thyroid cartilage (cricothyroid membrane).
3	Find the hard prominence just below the depression (cricoid cartilage).
4	Apply firm pressure while pinching with the thumb and index finger while applying firm pressure toward the patient's back and somewhat toward the head. This action presses the trachea back against the esophagus, compressing the esophagus. Cricoid pressure facilitates intubation because it pushes the tracheal orifice into the visual field of the person performing intubation.
5	Release pressure *only* when proper tube placement is confirmed and the cuff is inflated or when instructed to do so by the person performing intubation.

Ventilating With an ETT in Place During Chest Compressions

During cardiac or respiratory arrest provide the following:

- **Volume:** The volume should cause visible chest rise.
  - — When practicing this skill, try to get a sense of what such a volume feels like when squeezing the ventilation bag.
  - — Provide slightly more volume for very obese patients.

- **Rate:** Provide 8 to 10 breaths per minute (approximately 1 breath every 6 to 8 seconds) when delivering ventilation during CPR and 10 to 12 breaths per minute (approximately 1 breath every 5 to 6 seconds) for ventilation without chest compressions (ie, for respiratory arrest without cardiac arrest). Each breath should last 1 second.
- **Compression-ventilation cycles:** Once an advanced airway is in place, the compressing rescuer provides chest compressions at a rate of at least 100 per minute without pauses for ventilations. Compressors should rotate every 2 minutes.

Once the patient is in the hospital, obtain a chest x-ray as soon as possible to determine the depth of the ETT insertion. Look for incorrect placement into a main bronchus.

Never wait for a chest x-ray to check misplacement of the tube in the esophagus. You must detect esophageal insertion immediately by checking tube placement immediately after tube insertion. Confirm proper placement by physical exam and the confirmation techniques discussed below (Clinical and Device Confirmation of ETT Placement).

Take care to avoid air trapping in patients with conditions associated with increased resistance to exhalation, such as severe obstructive lung disease and asthma. Air trapping could result in a positive end-expiratory pressure (PEEP) effect that may significantly lower blood pressure. In these patients use slower ventilation rates to allow more complete exhalation. In cases of hypovolemia, restore intravascular volume.

Complications of ETT Placement

Several complications may occur with endotracheal intubation.

If the ETT is inserted into the esophagus, the patient will receive no ventilation or oxygenation unless he or she is still breathing spontaneously. If you or your team fails to recognize esophageal intubation, the patient could suffer permanent brain damage or die.

Use care when removing and replacing an incorrectly placed ETT. Use bag-mask ventilation and then reintubate after you address the higher priorities (ie, continuous chest compressions, defibrillation as needed, IV access). The ETT will help reduce the risk of gastric inflation, but the insertion process requires interruption of chest compressions and may produce additional complications.

If a laryngoscope and tube are not readily available or if the intubation attempt is not successful within 30 seconds, return to bag-mask ventilation. Provide 100% oxygen and attempt intubation again in 20 to 30 seconds.

Tube Trauma and Adverse Effects

Endotracheal intubation can cause significant trauma to the patient, including

- Lacerated lips or tongue from forceful pressure between the laryngoscope blade and the tongue or cheek
- Chipped teeth
- Lacerated pharynx or trachea from the end of the stylet or ETT
- Injury to the vocal cords
- Pharyngeal-esophageal perforation
- Vomiting and aspiration of gastric contents into the lower airway
- Release of high levels of epinephrine and norepinephrine, which can cause elevated blood pressures, tachycardia, or arrhythmias

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Insertion of ETT Into One Bronchus

Insertion of the ETT into the right (most common) or left main bronchus is a frequent complication. Unrecognized and uncorrected intubation of a bronchus can result in hypoxemia due to underinflation of the uninvolved lung.

To determine if the ETT has been inserted into a bronchus, listen to the chest for bilateral breath sounds. Also look for equal expansion of both sides during ventilation.

If you suspect that the tube has been inserted into either the left or right main bronchus, take these actions:

- Deflate the tube cuff.
- Withdraw the tube back 1 to 2 cm.
- Confirm correct tube placement.

- Recheck the patient's clinical signs, including chest expansion, breath sounds, and evidence of oxygenation.

You can also order a portable chest x-ray to check placement of the ETT. But remember, recognizing this complication is a clinical responsibility. You order an x-ray after clinical confirmation to assess correct ETT placement and tube position.

Endotracheal Administration of Resuscitation Medications

Endotracheal administration of medications is used if IV or IO access cannot be established. IV and IO are the preferred routes for drug administration. Providers use the memory aid NAVEL to recall naloxone, atropine, vasopressin, epinephrine, and lidocaine, each of which can be administered by ETT. Use the ETT route of administration *only if you cannot obtain IV/IO access.* In addition, you should use a dose that is approximately 2 to 2.5 times higher than the dose for IV/IO administration. Mix the dose of drug with 5 to 10 mL of normal saline or distilled water. (Note: Absorption of epinephrine and lidocaine is greater when these drugs are diluted with distilled water, but the water may cause more adverse effects on PaO_2.)

- As noted above, ETT doses of medications should be considerably higher than IV doses—in the range of 2 to 2.5 times the IV dose. For example, the recommended ETT dose of epinephrine is at least 2 to 2.5 mg.
- Once the medication has been administered through the ETT, perform 1 to 2 good ventilations to facilitate deposition of the drug into the airways.
- When equal amounts of the same drug are given by the IV and ETT routes, the serum concentration of ETT drugs is much lower than the serum concentration of IV drugs.

Confirmation of ETT Placement: Physical Exam

Confirm tube placement immediately, assessing the first breath delivered by the bag-mask device. This assessment should not require interruption of chest compressions. No single confirmation technique, including clinical signs or the presence of water vapor in the tube or device, is completely reliable, particularly when cardiac arrest is present. For this reason the AHA recommends the use of both clinical assessment and a device to confirm correct tube placement. Ideally you will attach a CO_2 detection device to enable detection of exhaled CO_2. 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. Stop ventilations. Remove the ETT at once. Then:

- Immediately resume chest compressions if CPR is in progress.
- Resume bag-mask ventilation or consider an alternate advanced airway.
- Reattempt intubation only after reoxygenating the patient (approximately 30 seconds of bag-mask ventilations using 100% oxygen).
- If, following intubation, the chest wall rises appropriately and stomach gurgling is not heard, listen to the lung fields with *5-point auscultation:* over the stomach, left and right anterior lung fields, and left and right midaxillary

lung fields. Document the location of breath sounds in the patient's medical record. If you have any doubt, stop ventilations through the tube.
- If there is still doubt about correct tube placement, use the laryngoscope to see if the tube is passing through the vocal cords.
- If the tube seems to be in place, reconfirm the tube mark at the front teeth (previously noted after inserting the tube 1 to 2 cm past the vocal cords).
- Secure the tube with a commercial device designed for this purpose or with tape.
- Once the tube is secured, insert a bite-block if the commercial device used to secure the tube does not prevent the patient from biting down and occluding the airway.

Confirmation of ETT Placement: Qualitative and Quantitative Devices

The *2005 AHA Guidelines for CPR and ECC* recommend confirmation of ETT with both clinical assessment and a device. If the device is attached to the bag before it is joined to the tube, it will increase efficiency and decrease the time that chest compressions must be interrupted.

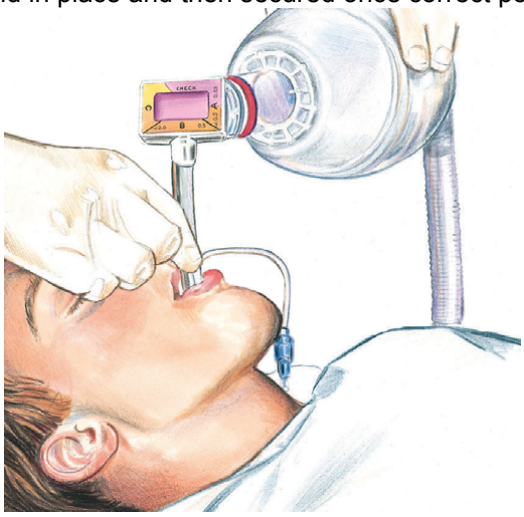
Providers should always use both clinical assessment and a device to confirm ETT location immediately after placement and each time the patient is moved. Detailed assessment of out-of-hospital intubation attempts has concluded that ETTs are (1) much more difficult to place properly in that setting and (2) highly susceptible to misplacement and displacement. Proper training, supervision, frequent clinical experience, and a process of quality improvement are the keys to achieving successful intubation.

A variety of electronic and mechanical devices are available for use in both the in-hospital and out-of-hospital settings. There are several models of end-tidal CO_2 detectors (qualitative, quantitative, and continuous) and of esophageal detector devices. These devices range from simple and inexpensive to complex and costly.

Exhaled (Qualitative) CO_2 Detectors

A number of commercial devices can react, usually with a color change, to CO_2 exhaled from the lungs. This simple method can be used as the initial method of detecting correct tube placement even in the patient in cardiac arrest (Figure 10). The qualitative detection device indicating exhaled CO_2 indicates proper ETT placement. The absence of a CO_2 response from the detector (ie, results are *negative* for CO_2) generally means that the tube is in the esophagus, particularly in patients with spontaneous circulation.

Figure 10. Confirmation of tracheal tube placement. **A,** End-tidal colorimetric carbon dioxide indicator: purple color indicates lack of carbon dioxide—probably in the esophagus. **B,** End-tidal colorimetric carbon dioxide indicators: yellow indicates the presence of carbon dioxide and tube in airway. Note that the carbon dioxide detection cannot ensure proper *depth* of tube insertion. The tube should be held in place and then secured once correct position is verified.



A

B

No CO_2 *detected but tube in trachea:* The tube is actually in the trachea, but a negative reading for CO_2 leads to unnecessary removal of the tube. These negative readings most commonly occur because end-tidal CO_2 production is minimal in cardiac arrest. Chest compressions during CPR produce an estimated 20% to 33% of normal blood flow to the lungs, so little if any CO_2 is exhaled. Negative readings also occur in patients with a large amount of dead space (eg, a significant pulmonary embolus).

CO_2 *detected but tube in esophagus:* The tube is in the esophagus, yet CO_2 was detected, leading to prolonged esophageal intubation. These positive readings have been reported in animals that had ingested large amounts of carbonated liquids before the arrest. This results in CO_2 release from the stomach into the esophagus during CPR. To avoid this problem, manufacturers suggest that you evaluate CO_2 detector readings after delivery of about 5 or 6 breaths.

Quantitative End-Tidal CO_2 Monitors

The quantitative end-tidal CO_2 monitor is a hand-held confirmation device. This device is a *capnometer.* It provides a single quantitative readout of the concentration of CO_2 at a single point in time. The *capnograph* provides a continuous display of the level of CO_2 as it varies throughout the ventilation cycle.

These monitors can confirm successful endotracheal tube placement within seconds of an intubation attempt. They also can detect patient deterioration associated with declining clinical status or endotracheal tube displacement. Displacement is an adverse event that is alarmingly common during out-of-hospital transport of a patient.

Esophageal Detector Devices

Esophageal detector devices (EDDs) (Figure 11) apply a suction force to the inserted end of the ETT. The suction force is created when you pull back the plunger on a large syringe (60 to 100 mL) or completely compress a flexible aspiration bulb. Once compressed, the bulb is firmly attached to the end of the tube coming out of the mouth and then released. If the tip of the tube is in the esophagus, the suction will pull the esophageal mucosa against the tip of the tube, preventing movement of the plunger or reexpansion of the suction bulb. There will be either no expansion or very slow reexpansion.

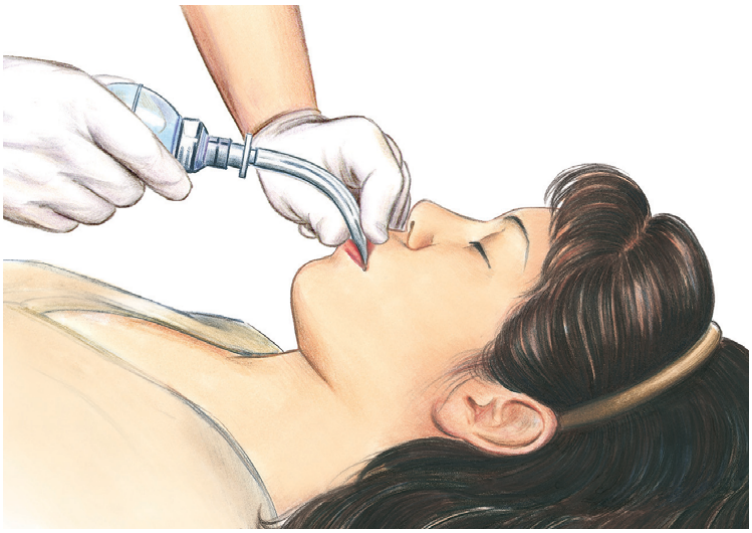


Figure 11. Esophageal detector device: aspiration bulb technique. Hold the tube in place until you confirm that it is in the correct position and then secure it.

Unlike the end-tidal CO_2 detector, the EDD does not depend on blood flow. However, although the device is generally sensitive for detection of ETT placement in the esophagus it is not specific for ETT placement in the trachea. In addition, it may yield misleading results in patients with morbid obesity, late pregnancy, or status asthmaticus. There is no evidence that the EDD is accurate for the continuous monitoring of ETT placement. For these reasons, the EDD should be considered one of several methods for confirmation of ETT placement.

Results suggest that the tube is not *in the esophagus when it* is *in the esophagus:* There are several ways in which the EDD can suggest that the tube is in the trachea (suction not maintained on bulb) when the tube is actually in the esophagus. The EDD indicates that the tube is in the trachea by rapid reexpansion of the suction bulb. But prior CPR or ventilations using a bag can fill the stomach or esophagus with air, causing the bulb to reexpand or the plunger to push out. The unwary rescuer, thinking the tube is in the trachea, may leave the tube in the esophagus, a potentially fatal error.

See Table 2 for a comparison of the qualitative performance of the EDD and end-tidal CO_2 device in terms of correct responses plus the most common causes of misleading results.

Causes of Misleading Results From End-Tidal CO_2 Detectors and EDDs

Table 2 lists possible causes of misleading results using end-tidal CO_2 detector devices and EDDs to confirm correct placement of the ETT. The columns (vertical) indicate the reading and actual location of the ETT. The rows (across) indicate the expected results from using either a colorimetric end-tidal CO_2 detector (A) or bulb-type esophageal detector device (B). With both devices assume that the rescuer made a conscientious intubation effort and thinks the ETT is in the trachea.

Table 2. Reasons for Misleading Results Using End-tidal CO_2 Detector and Esophageal Detector Device.

A: Colorimetric End-Tidal CO_2 Detector		
Reading	**Actual Location of ETT: Trachea**	**Actual Location of ETT: Esophagus (or Hypopharynx)**
Carbon Dioxide Detected Color change (or as specified by manufacturer) (positive = CO_2 present)	***ETT in trachea*** Proceed with ventilations.	***Reasons for apparent CO_2 detection despite tube in esophagus*** **Causes:** Distended stomach, recent ingestion of carbonated beverage, nonpulmonary sources of CO_2. **Consequences:** Unrecognized esophageal intubation; can lead to iatrogenic death.
No CO_2 Detected No color change (or as specified by manufacturer) (negative = CO_2 absent)	***No CO_2 detection with tube in trachea*** **Causes:** Low or no blood flow state (eg, cardiac arrest); any cardiac arrest with no, prolonged, or poor CPR. **Consequences:** Leads to unnecessary removal of properly placed ETT. Reintubation attempts increase chances of other adverse consequences.	***No CO_2 detection and tube is not in trachea (ie, tube is in esophagus)*** **Causes:** Rescuer has inserted ETT in esophagus/hypopharynx. A life-threatening adverse event has occurred. **Consequences:** Rescuer recognizes ETT is not in trachea; properly and rapidly identified; tube is removed at once; patient is reintubated.
B: Esophageal Detector Device		
Reading	**Actual Location of ETT: Esophagus**	**Actual Location of ETT: Trachea**
Consistent With Tube in	***Device suggests tube in esophagus when it is***	***Device suggests tube in esophagus when it is in***

Esophagus Bulb does not refill or refills slowly (>5 seconds × 2), or syringe cannot be aspirated, suggesting that tip of ETT is in esophagus	***in esophagus*** **Causes:** Rescuer has inserted tube in esophagus/hypopharynx. A life-threatening adverse event has occurred. **Consequences:** Rescuer correctly recognizes ETT is in esophagus; ETT is removed at once; patient is reintubated.	***trachea*** **Causes:** Secretions in trachea (mucus, gastric contents, acute pulmonary edema); insertion in right main bronchus; pliable trachea (morbid obesity, late-term pregnancy). **Consequences:** Leads to unnecessary removal of properly placed ETT. Reintubation attempts increase chances of other adverse consequences.
Consistent With Tube in Trachea Bulb fills immediately or syringe can be aspirated, suggesting that ETT is in trachea	***Results suggest that tube is NOT in esophagus (ie, that it is in trachea) when tube IS in esophagus*** **Causes:** • Conditions that cause increased lung expansion (eg, COPD, status asthmaticus). • Conditions that fill stomach with air (eg, recent bag-mask ventilation, mouth-to-mask or mouth-to-mouth breathing). • Conditions that cause poor tone in esophageal sphincter or increased gastric pressure (late pregnancy). **Consequences:** Unrecognized esophageal intubation can lead to death.	***Results suggest that tube is NOT in the esophagus (ie, that it is in the trachea) when it IS in the trachea.*** Esophageal detector device indicates ETT is in trachea. Proceed with ventilations.