# Verification of Endotracheal Tube Placement: A Comparison of Confirmation Techniques and Devices

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The properly placed endotracheal tube provides the definitive protected airway and is crucial to ensuring adequate ventilation in the event of cardiac arrest, respiratory failure, or significant trauma. Although unrecognized esophageal placement is rapidly fatal, it is not harmful if it is recognized quickly.[1] Nevertheless, many malpractice claims have been prosecuted successfully because practitioners did not recognize that they had improperly placed endotracheal tubes.[2-4]

Recent studies in busy urban EMS systems found that up to 25% of medical or trauma pediatric and adult patients had esophageal intubations on presentation to the emergency department.[5,6] In the uncontrolled world of EMS, lack of space and visibility often complicate intubation attempts. In addition, movement of patients and vehicles can easily result in the movement of endotracheal tubes.

In the hospital setting, whether one is moving a patient for diagnostic medical imaging or rolling down the hallway en route to the critical care unit, tubes can be pulled or moved. If the patient is combative, this possibility increases significantly. In infants and small children with proportionately smaller airways, just the simple flexion or extension of the neck can result in extubation. How, then, do we know if an endotracheal tube is actually in the trachea?

## Initial verification of endotracheal tube placement

### DIRECT LARYNGOSCOPY

Looking to see whether the endotracheal tube is going through the vocal cords is one of the best ways to determine the location of the tube and is considered the "primary" method of verification.[3,7] However, copious amounts of

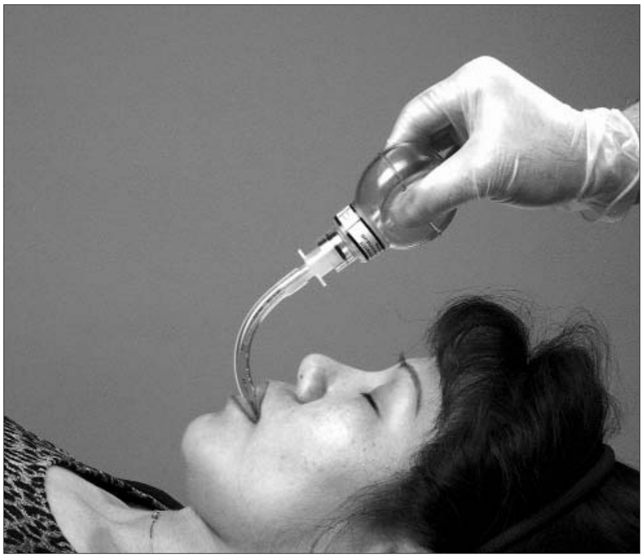

FIGURE 1
WolfeTory esophageal intubation detector. With an esophageal intubation, the less rigid structures of the esophagus collapse when the user attempts to aspirate air into the bulb- or syringe-style esophageal detection devices. The bulb will remain compressed and the syringe plunger will not withdraw easily. (Available in syringe [EID100] or bulb [EID200] models; manufactured in USA by Wolfe Tory Medical, Inc, Salt Lake City, Utah, phone (888)380-9808, Web site *www.wolfetory.com*).

blood or secretions in the line of sight can make direct visualization quite difficult. Anatomic irregularities, such as a large tongue, prominent teeth, or a short, thick neck, can further interfere with direct visualization, especially when cervical stabilization must be maintained. Because of these problems and the fact that the tube may become dislodged before or after it has been secured, there is an absolute need for "secondary" methods of verification.[1,3,7-9]

## Secondary verification of endotracheal tube placement

### "GURGLING" OVER THE EPIGASTRIUM

Some recent publications suggest that listening over the epigastrium is the first step after placing the endotracheal tube.[7,8] This method may provide a convincing indication of esophageal placement, but it does not provide positive verification of tracheal placement.[3,8,9]

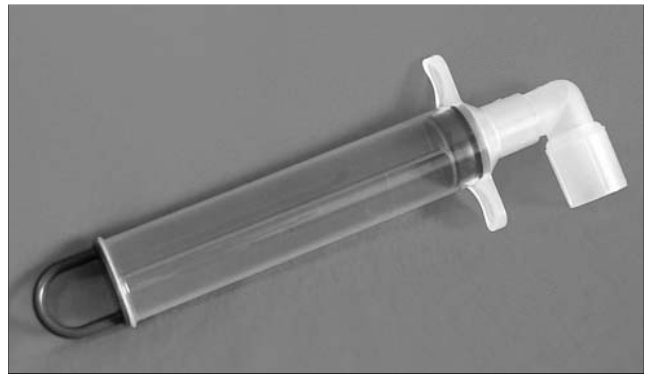

FIGURE 2
PosiTube. With an esophageal intubation, the less rigid structures of the esophagus collapse when the user attempts to aspirate air into the bulb- or syringe-style esophageal detection devices. The bulb will remain compressed and the syringe plunger will not withdraw easily.

### AUSCULTATING BREATH SOUNDS

Listening for breath sounds to verify tube placement has limitations, especially when the patient is an infant or a small child. In these patients, referred breath sounds can be heard throughout the chest, even with esophageal endotracheal tube placement. Also, breath sounds cannot be auscultated easily in very noisy environments.[3]

### MISTING IN THE ENDOTRACHEAL TUBE

Vapor condensation in the endotracheal tube is commonly found during exhalation. However, this finding is not conclusive because endotracheal tube misting can occur even with an esophageal intubation.[3,7]

### ESOPHAGEAL DETECTION DEVICE (EDD)

A "turkey baster" type of bulb device, such as the EID Esophageal Intubation Detector, or a syringe device, such as the PosiTube (Figures 1 and 2) is placed onto the endotracheal tube, with the desired result being re-expansion of the bulb or easy aspiration of air into the syringe. The cartilaginous rings of the trachea typically prevent the trachea from collapsing onto itself. Therefore, if the endotracheal tube is in the trachea, the trachea will maintain its structural integrity and air will pass into the device. With an esophageal intubation, the lack of supporting structures for the esophagus cause the esophagus to collapse, and air will not enter the EDD.

These devices may be useful in dark and noisy environments where visualization of colorimetric devices and auscultation may be difficult. They can be especially helpful in patients with very poor perfusion or those in cardiopulmonary arrest. However, EDDs may give misleading results in patients with morbid obesity, late pregnancy, status asthmaticus, or copious tracheal secretions. And whereas EDDs have been useful for adults and children, they appear to be unreliable in infants.[3]

CHEST RADIOGRAM

Considered for many years to be the standard of care for confirming endotracheal tube placement, many persons still highly recommend obtaining a chest radiogram to assess the position of the endotracheal tube in relation to the carina. However, in our opinion, it takes too much time to obtain and view the film.[3] In addition, the endotracheal tube may become dislodged during or after the radiogram is obtained. Furthermore, in the standard portable anterior-posterior view, an esophageal intubation can be very difficult to distinguish from a tracheal intubation because the esophagus lies directly behind the trachea.[7]

How, then, do we definitively confirm endotracheal tube placement? The answer may be end-tidal carbon dioxide ($CO_2$) detection.

### End-tidal $CO_2$ detection and monitoring

$CO_2$, a byproduct of cellular metabolism, is transported in the venous blood to the lungs, where it is eliminated during the expiratory phase of breathing. $EtCO_2$ refers to the amount of $CO_2$ present at the end of exhalation and indicates the adequacy of ventilation, perfusion, and gas exchange in the lungs. The normal range for $EtCO_2$ is 35 to 45 mm Hg.

$EtCO_2$ detection and monitoring can be used for both initial and ongoing verification of endotracheal tube placement, as well as for the assessment of a patient's respiratory status. $EtCO_2$ monitoring devices fall into 3 categories: colorimetric (changes color), capnometric (numeric; quantitative display), or capnographic (numeric display with waveform; qualitative display). Colorimetric $EtCO_2$ detectors can be purchased for less than $30; however, electronic capnometers and capnographs can range from several hundred to several thousand dollars.


FIGURE 3
EasyCap. Colorimetric devices are placed between the endotracheal tube and the resuscitation bag. They provide visual evidence of tracheal intubation by changing color in the presence of $CO_2$ in "exhaled" air. The extent of color change provides an indication of the amount of $CO_2$ detected, giving an indication of the status of pulmonary perfusion. (Reprinted by permission of Nellcor Puritan Bennett Inc, Pleasanton, Calif.)

Illustrating the effectiveness of this monitoring, staff in a teaching hospital's neonatal intensive care unit checked the $EtCO_2$ for 22 infants who had been intubated by residents. Eleven of the 22 endotracheal tubes were initially inserted in the esophagus. $EtCO_2$ detection devices immediately verified all correct and incorrect placements.[10]

### Colorimetric $EtCO_2$ detection devices

Colorimetric $EtCO_2$ devices change color in the presence of exhaled $CO_2$. The key to using these $EtCO_2$ detection devices successfully with patients of all ages and sizes is to allow adequate exhalation time so that the detector can change colors. In many cases, this means checking for a definitive color change after 6 ventilations.

The EasyCap (for adults) and Pedi-Cap (for infants and children) have variable color changes and a numeric scale showing the $EtCO_2$ levels (Figure 3). The color change for


FIGURE 4
Ventlab Airway Circulation Evaluator. Colorimetric devices are placed between the endotracheal tube and the resuscitation bag. They provide visual evidence of tracheal intubation by changing color in the presence of $CO_2$ in "exhaled" air. The extent of color change provides an indication of the amount of $CO_2$ detected, giving an indication of the status of pulmonary perfusion.

these devices and for the Capno-Flo resuscitation bag is easy to remember. If the indicator turns "good as gold," the endotracheal tube is likely to be in the trachea. If the adapter turns or remains purple, the endotracheal tube is probably in the esophagus. An initial purple reading on the device may indicate prolonged cardiac arrest, inadequate CPR efforts, respiratory insufficiency, or an esophageal intubation. After several ventilations, the color may change and the EtCO2 level, or the shade of coloration, will provide an indication of the level of improved cardiopulmonary function or the effectiveness of the CPR, in addition to verifying correct endotracheal placement.[11,12] According to the manufacturer, EasyCaps and Pedi-Caps are accurate for 2 hours of continuous use or 24 hours of intermittent use.[13]

Capno-Flo resuscitation bags for infants, children, or adults have a built in $EtCO_2$ detector, eliminating the need to remember to apply an $EtCO_2$ device. Ventlab Corporation recently introduced the Airway Circulation Evaluator that changes from white to purple in the presence of significant exhaled $CO_2$ (Figure 4).

Among the most impressive features of the EasyCap/Pedi-Cap devices is the breath-to-breath change in color. These rapid changes can verify proper endotracheal tube placement, not only initially, but subsequently as well. We have experienced several occasions in which the endotracheal tube was initially in the trachea (per colorimetric $EtCO_2$ verification), but immediately after the chest radiogram was taken, the adapter stopped changing from purple to gold, indicating a lack of $CO_2$ in the "exhaled" air. This change provided an early and convincing warning that the endotracheal tube was dislodged, even before we could detect the patient's oxygen desaturation. We provided corrective action before dangerous arrhythmias or cardiac arrest could occur.

We also have had several experiences in which we identified pulseless electrical activity (PEA) arrests by colorimetric $CO_2$ detection. In PEA arrest, virtually any rhythm can be seen on a cardiac monitor, but the patient has no pulse. In the air-medical transport environment, we have had several pediatric and adult trauma patients for whom, mid flight, the device stopped changing from purple to gold. Knowing that the endotracheal tube had been held in place, and with the cardiac monitor reflecting a sinus tachycardia, the lack of $EtCO_2$ indicated that these patients were most likely in a PEA arrest. The color change resumed with the return of adequate cardiac perfusion.

*Among the most impressive features of the EasyCap/Pedi-Cap devices is the breath-to-breath change in color. These rapid changes can verify proper endotracheal tube placement, not only initially, but subsequently as well.*

### Limitations with colorimetric devices

Colorimetric $EtCO_2$ detectors are extremely reliable as long as the patient is alive and has a perfusing cardiac rhythm and the device remains uncontaminated. In cases of limited pulmonary perfusion, very little $CO_2$ gets to the lungs to be exhaled and the adapter may not change color quickly if it changes at all. However, although it is less reliable, one can usually expect a color change in properly ventilated patients who have a nonperfusing rhythm but who are receiving adequate CPR.[3,11,14,15]

Fluids that may be found in and around the respiratory tract can affect the reliability of these devices. Because the device is placed directly between the resuscitation bag and the endotracheal tube, emesis, blood, and pulmonary secretions may contaminate it. If contamination occurs, the device must be replaced. With Capno-Flo bags, the $CO_2$ detector cannot be removed, and thus the entire bag must be replaced, adding to the cost of patient care. False-positive color changes can occur when the endotracheal tube is placed into the esophagus of a patient who has consumed a carbonated beverage very recently. The device may change to gold initially because of the $CO_2$ from the soft drink. To protect against this error, the manufacturer recommends examining the detector after 6 breaths for true verification of endotracheal tube placement. In the event of an esophageal intubation, the 6 breaths allow the $CO_2$ in the stomach to be dispersed.[13,15]

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If the endotracheal tube is placed in the hypopharynx, the device also may register a false-positive reading. In this position, ventilation of both the esophagus and trachea can occur, usually causing a color change in the detector. To avoid this situation, estimate the correct depth of the endotracheal tube by placing the "lip line" at the centimeter marking that is 3 times the size of the endotracheal tube. For example, an infant's 4.0 endotracheal tube should be taped at about the 12-cm line, and an adult's 8.0 endotracheal tube should be taped approximately at the 24-cm marking.[16]

FIGURE 5
The INdGO bag has a replaceable colorimetric device built into the design of the resuscitation bag and features "breath-to-breath" color changes. Even with a properly placed endotracheal tube, any colorimetric device may require up to 6 "breaths" before the user can detect a color change. (Reprinted by permission of Nellcor Puritan Bennett Inc, Pleasanton, Calif.)

A drawback of Capno-Flo Resuscitation Bags is that, unlike the EasyCap and Pedi-Cap, the built in $EtCO_2$ device on these bags does not produce true breath-to-breath color changes. However, once a color change is noted on the Capno-Flo (indicating proper placement and adequate perfusion), it does change back to purple if the endotracheal tube is dislodged or if perfusion stops. As with the original color change, the return to purple may take as many as 6 breaths. The manufacturer of the Capno-Flo resuscitation bags has recently released a "next generation" resuscitation bag (IndGO) with breath-to-breath color changes and built-in, replaceable $CO_2$ detectors (Figure 5).


FIGURE 6
Capnometers provide a numeric measurement of the concentration of $CO_2$ present in the exhaled air. These devices are available as portable units or as add-ons to bedside monitors.

#### Numeric capnometry

Numeric capnometry uses an electronic device that is connected directly to the endotracheal tube to verify proper placement with a quantitative display of the $EtCO_2$ level. However, some persons find that it is easier to remember "gold is good—purple is bad" rather than to remember the significance of a range of numbers. Also, these electronic monitors are more expensive than the disposable $EtCO_2$ devices, and body fluid contamination can compromise the accuracy of these devices as well[15] (Figure 6).

#### Capnography

Capnography not only provides verification of endotracheal tube placement but also provides continuous numeric (quantitative) and waveform (qualitative) indicators (Figure 7). These capabilities translate to quick and reliable evidence of endotracheal tube dislodgment, displacement, or obstructions. In addition, the ability to assess $CO_2$ levels accurately may provide valuable information regarding the patient's cardiopulmonary status and the response to


FIGURE 7
Capnography provides both continuous numeric (quantitative) and waveform (qualitative) indicators of $EtCO_2$. These instruments are valuable for their ability to provide ongoing monitoring of physiologic status as well as for verification of proper endotracheal tube placement. (Reprinted by permission of Nellcor Puritan Bennett Inc, Pleasanton, Calif.)

resuscitation and treatment. For inpatient critical care settings or in emergency departments where patients are maintained on ventilators, capnography can be valuable in determining the patient's response to and toleration of ventilator changes and weaning attempts and the depth of neuromuscular blockade.[12,16]

Endotracheal tubes can be lifesaving, but their improper placement, undetected, can be lethal. Primary and secondary verification and ongoing monitoring are critical to ensuring that the endotracheal tube is placed and remains in the trachea throughout resuscitation and ongoing care.

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