Review Article

Esophageal Intubation:
A Review of Detection Techniques

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Although the first reported oral intubation of the human trachea occurred in 1878 (1), the procedure did not become standard practice until many years later. It is now a routinely performed procedure, one of the first techniques to be encountered by the anesthesia trainee. It is performed by individuals of different backgrounds and levels of training in the operating suite, emergency room, intensive care unit, hospital ward, and in the field.

However, the frequency of tracheal intubation in modern anesthetic practice belies its importance, and the ability to accurately evaluate proper endotracheal tube position is crucial. A review of various anesthetic-related morbidity and mortality statistics (2–8) indicates that unrecognized esophageal intubation remains a problem, even among anesthesia personnel, a medical population specifically trained in such a procedure.

An analysis of anesthetic accidents reported to the Medical Defence Union of the United Kingdom from 1970 to 1978 revealed that nearly half the cases resulting in death or cerebral damage were due to faulty technique (2). The technique most often identified as the source of mishap was tracheal intubation, with inadvertent esophageal tube placement the usual problem (2). Another review of anesthesia-related medical liability claims in the United Kingdom from 1977 to 1982 listed esophageal intubation as a "main cause" of accidents leading to death or neurologic damage, with the largest claims resulting from such mishaps (6). An investigation of anesthesia mortality in Australia revealed 69% of the deaths to be related to airway management, with esophageal intubation once again identified as a contributing factor (7).

In the US, unrecognized esophageal intubation was identified as a significant problem in a study in one institution of cardiac arrests attributed solely to anesthesia (8). There were 27 cardiac arrests among 163,240 anesthetics over a 15-yr period. Of these 27 cardiac arrests, four were due to unrecognized esophageal intubation. In reviewing malpractice claims brought against Washington State anesthesiologists from 1971 to 1982, researchers found that esophageal intubation figured prominently among complications resulting in cardiac arrest, brain damage, and death (9). Of 192 claims, seven were brought for unrecognized esophageal intubation. In several of these cases, chest auscultation was recorded on the anesthetic record. The authors of this report emphasized that "even a conscientious, careful anesthesiologist may be unable to differentiate tracheal from esophageal intubation by the commonly employed methods" (9).

In a survey sponsored by the American Society of Anesthesiologists' Committee on Professional Liability, one of us (RJW) analyzed 29 anesthesia-related insurance claims in which unrecognized esophageal intubation was the cause of injury. In 18 of the 29 cases, auscultation of the chest was documented in the anesthetic record.

It is not only the frequency of misadventure but the potentially catastrophic consequences that underline the importance of being able to recognize and correct an esophageal intubation. We will review the reliability of commonly prescribed methods of assessing tube position after attempted endotracheal intubation, and then offer a solution to the problem.

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Commonly Prescribed Methods

Direct Visualization

Direct visualization of the vocal cords and watching as the tube passes into the trachea is considered by many the "gold standard" of correct tube placement and remains one of the most reliable signs. Unfortunately, this is impossible to achieve in certain patients, even in the most experienced hands, due to a multitude of factors. Even after visualization of the cords and tube placement, the tube may be inadvertently withdrawn from the trachea prior to or during securing of the tube, or with positioning of the patient in the lateral or prone position. Additionally, radiographic studies have shown that flexion or extension of the neck can change tube position as much as 5 cm, resulting in inadvertent extubation (10,11).

Chest Movement

Another commonly relied upon measure is observation of symmetric bilateral movements of the chest wall during ventilation. However, conditions in which ventilation is more than usually dependent on diaphragmatic movement make assessment of proper tube position by chest expansion difficult. In the patient with large breasts, obesity, a barrel chest from lung disease, or other conditions resulting in a rigid chest wall, chest movement can be difficult to evaluate.

More important, movement of the chest wall simulating ventilation of the lungs can be seen with an esophageally positioned tube. Confirmation of this phenomenon exists in numerous anecdotal reports of expansile upper thoracic movements noted with an ultimately diagnosed esophageal intubation (12–15). Pollard and Junius (12) demonstrated chest movements "identical to those seen when the lungs are inflated" with ventilation through an endotracheal tube intentionally inserted into the esophagus of a recently deceased man prior to the onset of rigor mortis. Progressive dissection from the epigastrium cephalad showed the chest movements were caused by "the flat esophagus distending into a firm tube which lifted the heart and upper mediastinal structures forward, thus elevating the sternum and ribs" (12).

Mechanisms other than balloon-like esophageal expansion have been proposed. Distension of the stomach with air can cause outward movement of the epigastrium, mimicking downward diaphragmatic movement and outward movement of the lower chest. Escape of gas from the stomach up the esophagus with release of bag compression would allow the diaphragm to fall and the lower chest to move inward (12,13).

Breath Sounds

The presence of bilateral breath sounds upon apical and/or midaxillary auscultation of the lungs would seem to be strong reassurance of proper tube position, based on experience, common sense, and some studies (16). However, the literature documents numerous cases (12–15,17) with experienced clinicians where apparently "normal" breath sounds were present with esophageal ventilation. Air passing through the esophagus has been noted to resemble coarse or tubular breath sounds (17,18). Howells and Riethmuller (13) suggest that the combination of "esophageal wall oscillation with gas movement and acoustic filtering" can produce wheezes similar to adventitial sounds arising from the lungs.

In addition, with mechanical or hand ventilation, gas flows tend to be faster, tidal volumes larger, and distribution different from what is observed with spontaneous respiration. Breath sounds are more predominantly bronchial and may differ in quality, depending on whether the chest is auscultated over the midline or laterally (12). This may explain why sounds produced by air movement through an esophageal tube may be mistakenly identified as breath sounds.

Epigastric Auscultation and Observation

Auscultation of the epigastrium to determine the absence of air movement in the stomach is recommended by some as a maneuver to be done before thoracic auscultation itself (17). Yet vesicular breath sounds can be transmitted to the epigastric area of tracheally intubated thinner or smaller individuals, such that differentiation between gastric air movement and breath sounds may be difficult.

Along with auscultation of the epigastrium comes observation of the abdomen for gastric distension. With esophageal reflux of air, the abdomen does not necessarily progressively distend with intermittent gastric inflation (12,15). Linko et al. (16) point out that gradual gastric filling can be difficult to distinguish from normal abdominal movements. The presence of gastric distension might also be attributable solely to mask ventilation prior to attempted intubation.

Presence of Exhaled Tidal Volumes

An additional point of emphasis is the possibility of measurable tidal volumes during the triad of spontaneous respiratory efforts with the esophagus intubated and the trachea obstructed. Robinson (19) documented tidal volumes up to 180 ml and peak flows greater than 50 L/min under these circumstances. With prior consent obtained, patients were tracheally intubated and allowed to breathe spontaneously. The esophagus was then intubated and the tracheal tube deliberately occluded. With spontaneous respiratory efforts, high intrapleural pressures were generated and transmitted to the esophagus. The degree of reservoir bag movement depends on the strength and coordination of the ventilatory effort and on the fresh gas flow rate, but patients may be able to move the bag and mimic normal respiration in such a setting.

Reservoir Bag Compliance

Another practice commonly adhered to is noting the characteristic feel of the reservoir bag associated with normal lung compliance during inspiration and the presence of expiratory refilling of the bag during hand ventilation. However, compliance varies widely from one person to another and within the same individual at different times. Repeated filling and emptying of the stomach with esophageal ventilation, leading to inflation and deflation of the breathing bag, can also be mistaken for pulmonary ventilation (12,13,16,20).

Endotracheal Tube Cuff Maneuvers

With the cuff deflated, the higher pitched sound of air escaping around a tracheal tube, compared to the more guttural sound of leakage around an esophageal tube, has been used as a distinguishing feature. However, with the cuff of an esophageal tube located near the level of the cricoid cartilage, the distinction in air sound may no longer exist (12).

Palpation of the endotracheal tube cuff in the neck to verify position has also been reported to fail (20), perhaps because the easily distensible esophagus simply balloons outward with an inflated cuff inside it.

Air Escape

A less commonly performed procedure involves pressing sharply on the sternum while listening over the tube opening to detect "a characteristic feel and sound of expelled air" (12). This is unreliable because of inability to distinguish between air expelled from a tracheal tube from: a) that passing through or around an esophageal tube; b) esophageal air present from mask ventilation prior to intubation; or c) air expelled from the nose.

Tube Condensation

Condensation of water vapor in the tube lumen, although less likely with esophageal intubation, can occur and hence is not a reliable sign. Conversely, the absence of condensation normally seen with a tube positioned in the trachea would be reason to look for further proof of correct tube position.

Gastric Contents

The presence of gastric contents in the tube (21) and/or the "death rattle" sometimes produced by the entrance of gastric fluid into the tube lumen (15) have led to the diagnosis of esophageal intubation. This may be difficult to distinguish from sounds produced by aspirated fluid or excessive secretions in an endotracheal tube.

Chest Radiography

Chest radiography to verify proper tube position is clearly too time-consuming and expensive, yet not a fail-safe even when performed. A prolonged esophageal intubation occurred during which a radiologist, pulmonary fellow, and additional residents failed to note malposition of the endotracheal tube border outside the tracheobronchial column in not one but two radiographs (21).

Video Stethoscope

Huang et al. (22) demonstrated the possibility of intraoperative use of a "video stethoscope" to ascertain lung ventilation. The device involves a small plastic electrocardiographic electrode casing fitted with a microphone and placed on skin overlying each hemithorax. By displaying the sound from each microphone on an oscilloscope screen in an X-Y format, distinct visual patterns were produced by esophageal, right main stem bronchial, and normal tracheal intubation. The device "conveniently and reliably provided continuous assurance of bilateral ventilation" in a patient population of 25 (22). This device, however, is relatively awkward and time-consuming to use.

Fiberoptic Bronchoscopy

Visualization of tracheal rings and carina by fiberoptic bronchoscopy is a reliable method of verifying tracheal tube placement. However, the instrument is relatively expensive, prone to breakage, and the method is unwieldy for routine use.

Eschmann Endotracheal Tube Introducer

The Eschmann endotracheal tube introducer (Downs Surgical, Decatur, GA) (Fig. 1), a narrow 60-cm-long

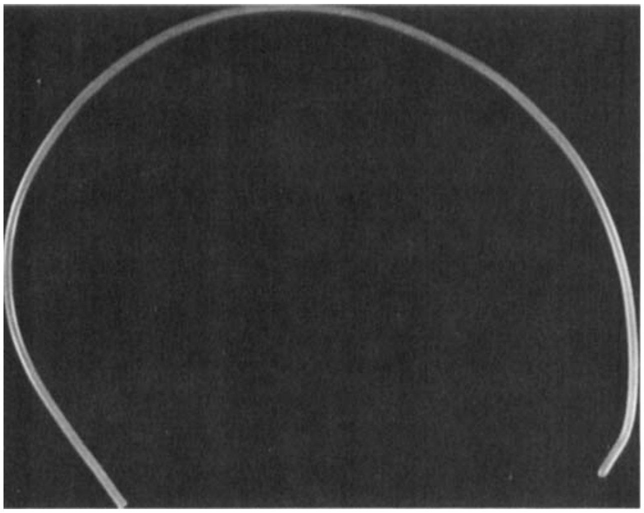

Figure 1. Eschmann endotracheal tube introducer.

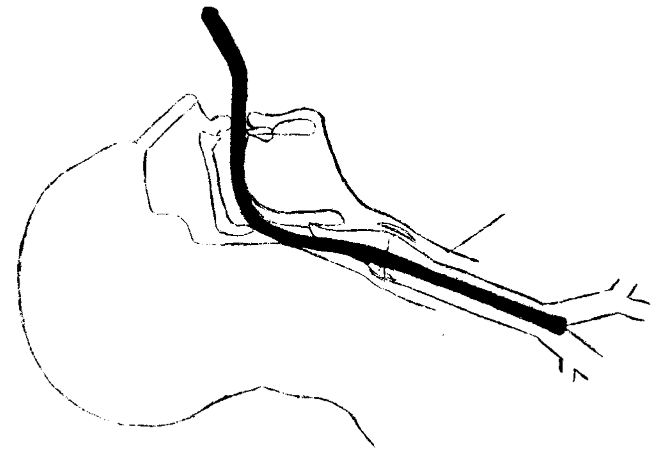

Figure 2. Introducer in trachea.

woven fiberglass stylet, is used at our institution as a test of proper tube position when there is question regarding tube placement, and end-tidal carbon dioxide measurement is not available. Upon insertion through the lumen of a tracheal tube, it will meet the carina at approximately 28–32 cm, or the distinct resistance offered by the cartilage of a main stem bronchus (Fig. 2). With the tube in the esophagus, the introducer will pass unopposed to distal esophagus or stomach (Fig. 3). This maneuver is too cumbersome for routine use, but is helpful in emergencies when end-tidal CO_2 measurement or a fiberoptic bronchoscope is not available.

Pulse Oximetry

Pulse oximetry, although useful in many situations, may be a late indicator of esophageal intubation for several reasons. Several authors (12,16,21) have noted normal functioning of a ventilator when connected to an esophageal tube. With the vocal cords relaxed, mechanical (or manual) ventilation into the esophagus can cause alveolar gas exchange. In 18 of the 20 patients studied by Linko et al. (16), after deliberate intubation of both esophagus and trachea, ventilation into the esophagus also caused ventilation of the lungs, as evidenced by carbon dioxide recordings obtained from the open endotracheal tube. The mechanism postulated was a "cyclic external compression of the lungs by the distending stomach and esophagus" (16). Therefore, in the clinical situation where the vocal cords have been relaxed (abducted) by the administration of neuromuscular blocking agents, esophageal ventilation can cause ventilation of the lungs, albeit with room air. This is significant because ventilation of the lungs with room air will considerably slow the onset of hemoglobin desaturation and cyanosis after esophageal intubation. This can delay recognition of tube misplacement until surgery is in progress or distractions such as record keeping are taking place. Another factor that significantly slows the onset of hypoxia after esophageal tube misplacement is preoxygenation prior to intubation (12,17,23,24). Detection of hemoglobin desaturation with pulse oximetry may therefore provide a relatively late sign of tube malposition.

End-Tidal Carbon Dioxide Measurement

Perhaps the most reliable and simple determination of proper tube placement involves capnometry, the measurement of carbon dioxide concentration during the respiratory cycle, and/or capnography, the display of this concentration in a wave form on a screen or paper graph. The reliability of carbon dioxide monitoring is based on the assumption that CO_2 can be reliably detected in patients with an intact pulmonary circulation whose trachea is intubated, whereas no CO_2 is present in gases exiting from an esophageal tube.

Easily identifiable CO_2 curves are obtained with ventilation through the trachea (16,25,26). Carbon dioxide can be detected initially with esophageal intubation when expired CO_2 has been forced into the stomach during prior mask ventilation. However, the end-tidal CO_2 is low in such cases, the wave pattern irregular, and CO_2 levels rapidly diminish with repeated ventilation, making it easy to distinguish between intratracheal and intraesophageal tracings (16).

There are a number of commercially available de-

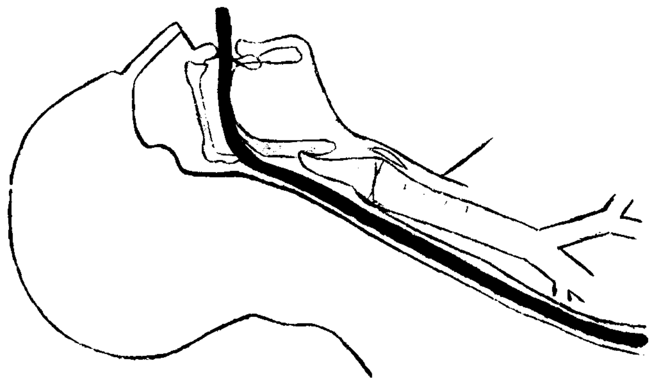

Figure 3. Introducer in esophagus.

Table 1. Evaluations of Methods of Assessing Tube Position

Documented incidents of failure	Reference
End-tidal carbon dioxide measurement	None
Direct cord visualization	None
Equal bilateral breath sounds	12–15, 17
Symmetric bilateral hemithorax elevation	12–16
Epigastric auscultation and observation	12, 15–17
Reservoir bag compliance and refilling	12, 13, 16, 20
Presence of tidal volumes with respiratory effort	19
Normal ventilator function	12, 16, 21
Cuff palpation in neck	20
Quality of air sound escaping around tube	12
Chest radiography	21

vices for measuring carbon dioxide, such as apnea monitors, of which there are approximately 30 different models, ranging in price from $1100 to $10,250 (27). Among the devices employed at our institution is the portable Tri-Med system (Biochem International, Inc., Waukesha, WI), used in the operating suites, with the intensive care unit ventilators, and available during emergency intubations throughout the hospital and in the field (28). It produces a quantitative readout of minute respiratory rate based on qualitative measurement of carbon dioxide. There are also some 16 different quantitative carbon dioxide analyzers on the market, from $2995 to $7885 (29), which produce a quantitative readout of end-tidal carbon dioxide levels.

Finally, the mass spectrometer can produce a continous CO_2 wave form, as well as a digital value. Such a setup allows for rapid diagnosis of accidental intraoperative disconnection of the breathing circuit between ventilator and endotracheal tube, an event identified by Cooper et al. as the most frequent "preventable anesthetic mishap" (30). Intraoperative tube obstruction from secretions or kinking also can be diagnosed. Even inadvertent movement of the tube tip from the trachea into the retropharynx can be detected by the distinctly different end-tidal CO_2 wave forms produced (26). Others (31) have emphasized the noninvasiveness of such monitoring, and have stressed that no other parameter can so readily evaluate the status of both the ventilatory and metabolic systems. Duberman and Bendixen (32) state that "the capnometer is the best device for warning of an undetected esophageal intubation." An assessment of human and technology-related anesthesia errors by a nonprofit biomedical engineering research firm notes that, combined with blood pressure and heart rate measurement, carbon dioxide monitoring "comes closest to being a fail-safe monitor for most problems that can cause anoxia and death" (33).

In summary, tracheal intubation is a maneuver today so routinely performed in anesthesia that it no longer receives the respect it deserves and the attention it demands. Undiagnosed esophageal intubation continues to figure prominently in anesthesia-related morbidity and mortality. Most of the commonly utilized methods of assessing tube position have been documented to fail under certain circumstances (Table 1). End-tidal carbon dioxide measurement is at present perhaps the most reliable means under all circumstances of determining proper tube position and should be employed routinely whenever possible.

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