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CLINICAL CONCEPTS

Airway

Preventing unrecognized esophageal intubation in the emergency department

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Abstract

Tracheal intubation is a commonly performed procedure on critically ill patients in the emergency department. It is associated with many serious complications, one of the most dangerous being unrecognized esophageal intubation, which can result in anoxic brain injury, cardiac arrest, or death. It is the responsibility of the emergency physician to do everything possible to avoid this devastating complication. Preventing unrecognized esophageal intubation requires a two-pronged approach. First, the inadvertent placement of intended tracheal tubes into the esophagus must be reduced as much as is humanly possible. This can be achieved with the routine use of video laryngoscopes for emergency department intubations. Numerous studies have demonstrated that use of video laryngoscopes can significantly reduce the occurrence of esophageal intubation, presumably by providing an improved view of the larynx. Second, if an esophageal intubation inadvertently occurs, it must be rapidly identified and appropriately addressed. The cornerstone of rapid identification is the use of continuous waveform capnography to detect exhaled carbon dioxide. Capnography has been shown to be the most accurate method to determine tube placement after intubation. Standard clinical examinations, for example, auscultation of breath sounds, visualization of chest excursion, and observation of condensation in the tube, have all been demonstrated in studies to be unreliable and thus should not be used to *exclude* esophageal intubation. Recently, the Project for Universal Management of Airways, an international collaborative of airway experts from anesthesiology, critical care and emergency medicine, published evidence-based guidelines to specifically address the issue of preventing unrecognized esophageal intubation. These guidelines, which have received endorsement from several prominent airway societies, including the Society for Airway Management, the Difficult Airway Society, and the European Airway Management Society, will be briefly discussed in this review.

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1 | INTRODUCTION

Critically ill patients in the emergency department (ED) frequently require invasive lifesaving procedures to be performed on them. One of the most critical interventions performed by emergency physicians is tracheal intubation, which is most commonly accomplished with rapid sequence intubation (RSI).[1] Intubation in the critically ill is associated with a fairly high prevalence of complications including hypoxemia, hypotension, and cardiac arrest.[1,2] A National Emergency Airway Registry (NEAR) study that included 17,583 intubations over a 10-year period found that inadvertent esophageal intubation occurred in 3.4% of attempted intubations performed in the ED.[1] Although the vast majority were recognized immediately, almost 4% of these esophageal intubations had delayed recognition. Unrecognized esophageal intubation, or delayed recognition of esophageal intubation, can lead to very serious complications including critical hypoxemia, aspiration, anoxic brain injury, cardiac arrest, and death. An older registry study of emergency intubations performed outside the operating room, before the widespread availability of capnography, found that delayed recognition of esophageal intubation was associated with over a 5-fold increase in critical hypoxemia, a 16-fold increase in aspiration, and a 14-fold increase in peri-intubation cardiac arrest.[3] This highlights the importance for emergency physicians to be able to rapidly recognize and appropriately respond to esophageal intubations in the ED to avoid serious patient harm and potentially catastrophic patient outcomes. Although there have been a multitude of airway guidelines published over the last 2 decades, none have been specifically dedicated to the issue of preventing unrecognized esophageal intubation.[4–7] Recently the Project for Universal Management of Airways, known as PUMA, (https://www.universalairway.org) published evidence-based guidelines titled "Preventing Unrecognized Oesophageal Intubation: A Consensus Guideline from the Project for Universal Management of Airways and International Airway Societies" in the journal *Anaesthesia*.[8] Although these guidelines were published in an anesthesiology journal, their content and message is relevant to all clinicians involved in airway management, including emergency physicians. It is important for emergency physicians to be familiar with techniques to avoid esophageal intubation, and to rapidly identify one when it occurs, as patients in the ED are often physiologically compromised and thus very intolerant of esophageal intubation and multiple intubation attempts.[9,10] As emergency physician members of the PUMA working group who were actively involved in the development of the PUMA guidelines, we will present highlights from this document to raise awareness on the importance of this issue with the hope of reducing patient harm in critically ill patients requiring emergency intubation.

2 | METHODS TO REDUCE UNRECOGNIZED ESOPHAGEAL INTUBATIONS

Prevention of unrecognized esophageal intubation requires a two-pronged approach. First, efforts must be made to minimize esophageal intubations that occur during airway management. Second, if an esophageal intubation inadvertently occurs, it must be rapidly identified and corrected before patient harm develops.

2.1 | Routine use of a video laryngoscope to minimize the occurrence of esophageal intubation

In terms of minimizing the occurrence of esophageal intubation, the data are quite clear on this. Routine use of a video laryngoscope (VL) helps reduce the prevalence of esophageal intubation.[11–14] An observational study of 3425 intubation attempts in an academic ED found that when a direct laryngoscope (DL) was used an esophageal intubation occurred in 5.1% of attempts.[11] When a VL was used esophageal intubation occurred in 1.0% of attempts. A propensity score matched analysis demonstrated that the odds ratio for the occurrence of esophageal intubation for DL, compared to VL, was 6.9. These results are supported by a recently updated Cochrane review of DL versus VL which found that use of a VL, both standard geometry and hyperangulated, reduced the risk of esophageal intubation by 50%.[14] It is not surprising that VL is so effective at reducing esophageal intubations as multiple studies have demonstrated that VL significantly improves the grade of laryngeal view and reduces intubation difficulty.[15] Routine use of a VL for emergency intubation in the ED can help reduce the occurrence of unrecognized esophageal intubations by simply reducing the occurrence of esophageal intubations in the first place, and thus is recommended whenever feasible.

2.2 | Routine use of capnography to rapidly detect esophageal intubation

Once an esophageal intubation inadvertently occurs, the goal is to rapidly identify it and correct it before patient harm occurs. Although there are multiple ways to exclude esophageal placement of a tube intended to be placed in the trachea, the cornerstone is the detection of exhaled carbon dioxide (CO_2) There are several devices currently available to detect exhaled CO_2, the most accurate being continuous waveform capnography.[16–18] Capnography uses an infrared light to measure the CO_2 concentration in exhaled gas and this information is then graphically displayed over time as a capnogram. A normal capnogram has a trapezoidal shape with a nearly vertical upstroke during exhalation due to rapid emptying of the alveoli, a very slightly up trending plateau as alveolar emptying continues, and a vertical downstroke as inhalation occurs and CO_2 is rapidly washed away with inspired gas. The end-tidal CO_2 ($ETCO_2$) is the partial pressure of CO_2 at the end of exhalation and is seen on the capnogram at the end of the plateau just before the inspiratory down stroke. Capnography is the gold standard for confirmation of intubation as studies have universally found that it is the most accurate technique to confirm placement of the tube in the respiratory tract with both a sensitivity and specificity of nearly 100%.[16,17] Equipment for waveform capnography should be available in all EDs and should be used for every

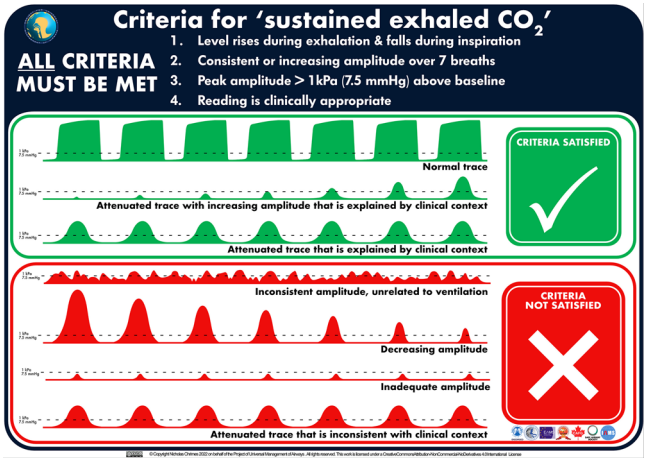

FIGURE 1 Criteria for sustained exhaled CO_2 (Reproduced with permission, Project for Universal Management of Airways)

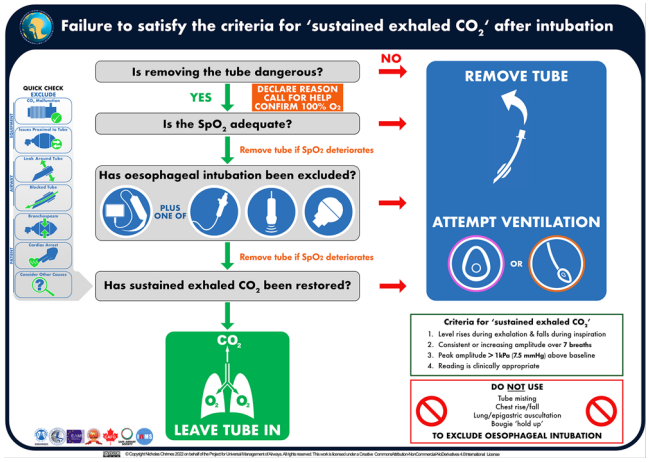

FIGURE 2 Algorithm to navigate situations where there is failure to achieve sustained exhaled CO_2 (Reproduced with permission, Project for Universal Management of Airways)

intubation. Ideally, capnography should be set up and used during the preoxygenation phase of RSI to ensure that the equipment is functioning properly before intubation. After intubation, the team should ascertain that a capnogram demonstrating exhaled CO_2 is present to confirm that the tube is correctly placed in the respiratory tract. As esophageal intubation is not necessarily always associated with a completely flat CO_2 trace, the concept of "sustained exhaled CO_2" was developed by the PUMA group to clearly define what constitutes a minimum adequate CO_2 trace to exclude esophageal intubation. Sustained exhaled CO_2, and thus confirmation of that the tube is in the respiratory tract, can be acknowledged if the following criteria are met (Figure 1):

1. The level of CO_2 rises and falls appropriately with exhalation and inhalation.
2. There is consistent or increasing amplitude of the capnogram over 7 breaths.
3. The peak amplitude of CO_2 is 7.5 mm Hg above the baseline.
4. The capnogram is clinically appropriate.

3 | FAILURE TO ACHIEVE SUSTAINED EXHALED CO_2 AFTER ATTEMPTED INTUBATION

After attempted tracheal intubation the first step to confirm correct placement of the tube is to evaluate for the presence of sustained exhaled CO_2. If the criteria described above are not met for sustained exhaled CO_2, then rapid action and decision-making are warranted. The PUMA esophageal intubation guidelines provide an algorithm to safely navigate this situation (Figure 2). The first 2 questions the clinician must ask themselves in this situation are:

1. Is there an obvious and immediately remediable cause for the absence of sustained exhaled CO_2?
2. Is removing the tube dangerous?

It should be noted that even in cardiac arrest there should be a capnogram with compressions. Although exhaled CO_2 will be attenuated to varying degrees depending on the clinical circumstances, it will almost always be present. The trace should almost never be completely flat. Likewise, severe bronchospasm almost always will result in detection of exhaled CO_2, except in extreme cases where there is no ventilation occurring at all. Although this rare scenario should be clinically obvious to the practitioner, it still cannot be assumed to be the cause of the absence of sustained exhaled CO_2. Misattribution of the absence of adequate CO_2 detection to cardiac arrest or bronchospasm are recurrent themes in fatal cases of unrecognized esophageal intubation (https://www.universalairway.org/puoi/cases). Thus, even if there is a strong clinical suspicion that the $ETCO_2$ readings are erroneous, the operator should remove the tube unless doing so would be dangerous. In most patients, even in patients undergoing RSI, the danger is likely to be low and thus the default action should be to remove the tube. Removing the tube is the fastest, simplest, and most definitive way to eliminate the possibility of esophageal intubation. Before reintubating, the guidelines recommend reoxygenating with a face mask or a supraglottic device. Detection of exhaled CO_2 when ventilating with an alternate device excludes any patient and equipment issues and thus confirms the tube as the source of the problem. This information can be crucial if sustained exhaled CO_2 is again absent on subsequent intubation attempts.

4 | VALID ALTERNATIVE TECHNIQUES TO EXCLUDE ESOPHAGEAL INTUBATION

In situations where removing the tube is considered dangerous and oxygen saturations are clinically safe, the PUMA guidelines specify a limited number of "valid alternative techniques" to exclude esophageal intubation (Figure 3). Repeat laryngoscopy, preferably with a VL, is advocated as a first line approach, supplemented by one other technique whenever feasible, because repeat laryngoscopy has

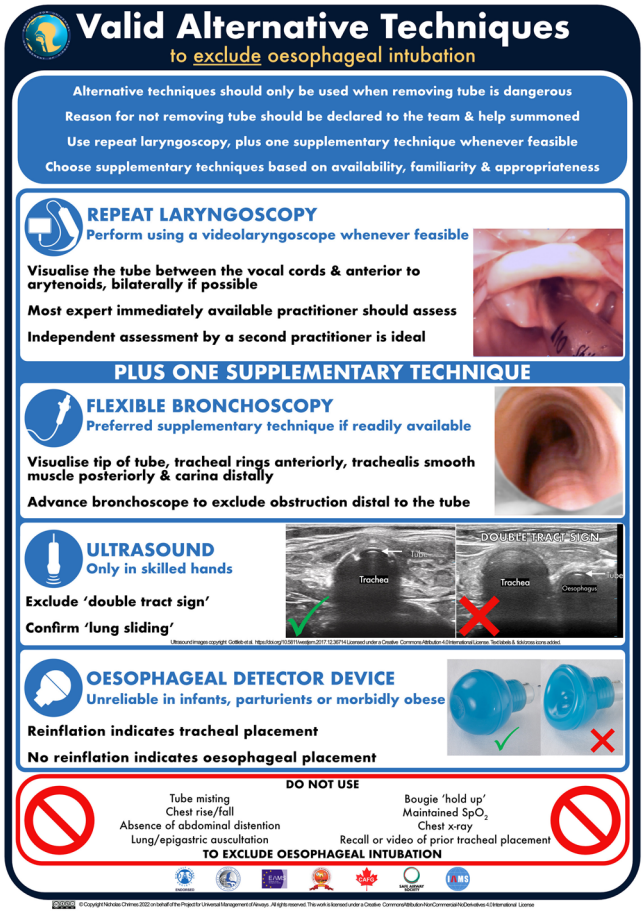

FIGURE 3 Valid alternative techniques to exclude esophageal intubation (Reproduced with permission, Project for Universal Management of Airways)

often yielded falsely reassuring results in many documented cases of unrecognized esophageal intubation (https://www.universalairway.org/puoi/cases). Use of a flexible endoscope to identify the tracheal rings can also be used for visual confirmation of the location of the tube, although this may take an unacceptable amount of time if the equipment is not immediately available or the clinician is not familiar with it. Another viable technique to exclude esophageal placement is the use of point-of-care ultrasound on the anterior neck. Ultrasound has been shown to be very accurate in excluding esophageal intubation in the hands of practitioners skilled in its use.[19,20] If the tube is in the esophagus a "double tract sign" can be seen, which is an echogenic shadow observed lateral to the trachea and is caused by the presence of the tube in the esophagus. A recent systematic review of 17 studies found that transtracheal ultrasound was 99% sensitive and 97% specific for determination of tube placement with a mean time to confirmation of 13 s.[20] However, similar to flexible endoscopy, if the ultrasound machine is not readily available or the clinician is not adequately skilled in its use, unacceptable delays may occur. Another device with reported excellent accuracy is the esophageal detector device (EDD).[21] This simple, inexpensive device consists of a compressible bulb with a 15-mm connector. The bulb is compressed to expel the air in it and then it is tightly connected to the tube. If the tube is in the esophagus, the negative pressure generated by the compressed bulb causes the soft esophageal walls to collapse around the tube, and thus the bulb will not re-expand. If the tube is in the trachea, the rigid tracheal rings prevent its collapse and thus air from the respiratory tract causes the bulb to rapidly re-expand. It is important to note that the EDD can give a false-negative result in certain patient populations such as infants, parturients and morbidly obese patients.[22–24]

5 | ALTERNATIVE METHODS TO DETECT EXHALED CO_2 AFTER ATTEMPTED INTUBATION

Although waveform capnography is the preferred method of detecting exhaled CO_2 due to its excellent accuracy, there may be circumstances where it is not readily available or not functioning properly. In these circumstances, alternative methods to detect exhaled CO_2 can be used. Capnometry uses a small battery-operated electronic device that is connected in-line with the airway circuit, and gives a continuous numeric readout of the $ETCO_2$.[17,25] Although capnometers are very accurate in measuring CO_2, they do not provide the additional valuable information that can be obtained by inspecting the morphology of the capnogram and the pattern of the capnography trace.[26,27] Another commonly used device to detect exhaled CO_2 is a colorimetric CO_2 detector. Although sometimes referred to as colorimetric capnometry or colorimetric capnography, these terms are inaccurate as these devices do not quantify the amount of CO_2 nor do they graphically display the data.[18,28,29] These disposable colorimetric devices are comprised of a plastic housing that contains paper that is impregnated with a pH sensitive dye. In the presence of adequate amounts of CO_2 (>15 mmHg) the paper becomes acidic causing the dye to change from purple (or blue) to yellow. As ventilation is performed, the paper disc oscillates between yellow during exhalation and purple (or blue) during inhalation. The paper turns a tan color when the partial pressure of CO_2 is <15 mmHg, and this result is considered "indeterminate." Unfortunately, these colorimetric detectors are not nearly as accurate as capnography and can give unreliable results in low flow states such as cardiac arrest.[30,31] One study of 110 emergency intubations found that the colorimetric CO_2 detector had a sensitivity of only 62% when used in patients intubated for cardiac arrest.[30] This is in contrast to a sensitivity of 98% that was found in the cohort of patients intubated for respiratory failure. It is important to note that if the paper in these devices becomes contaminated with excessive amounts of moisture or liquids the color changes cease to occur and the device is no longer reliable or usable. Contamination with acidic material, such as gastric contents, can turn the paper yellow and thus can give a false-positive result with an esophageal intubation.[32,33]

6 | UNRELIABILITY OF STANDARD CLINICAL SIGNS IN EXCLUDING ESOPHAGEAL INTUBATION

It is important to note that the commonly used clinical assessments to determine tube placement, such as auscultation of the chest and

epigastrium, visualization of chest excursion, and observation of condensation in the tube, should not be used to exclude esophageal intubation. All of these signs have been shown to be unreliable in excluding esophageal intubation.[17,34–37] Indeed, affirmation of these clinical findings are often documented in cases of unrecognized esophageal intubation, where it was ultimately discovered that the tube was not in the trachea. Pulse oximetry, which is a very important monitoring device during airway management, cannot be used to exclude esophageal intubation because effective preoxygenation can result in a large oxygen reservoir that can prevent oxygen desaturation for several minutes after an esophageal intubation.[38] Chest radiography, although useful in determining tube position in the respiratory tract, cannot be used to exclude esophageal intubation. On a one-dimensional anterior-posterior portable chest radiograph the tube can be in the esophagus yet appear to be in the anteriorly positioned trachea.[36]

7 | SUMMARY

In summary, unrecognized esophageal intubation is a potentially catastrophic complication that can result in significant patient harm and even death. Unfortunately, it continues to occur in all environments where airway management occurs, including in the ED. Airway management is a fundamental skill set for all emergency physicians and it is our responsibility to do everything we can to avoid unrecognized esophageal intubation. VLs should be available in all EDs and emergency physicians should be skilled and comfortable with their use. Routine use of VLs is encouraged for emergency intubation due to their proven efficacy in reducing esophageal intubations. Similarly, waveform capnography, the most reliable method for excluding esophageal intubation, should be available in all EDs and should be used on all intubated patients. Emergency physicians should be skilled in the interpretation of capnography and understand the criteria for sustained exhaled CO_2. If there is doubt regarding correct placement of a tube after attempted tracheal intubation, the tube should be immediately withdrawn in most circumstances. Although this occasionally may result in the removal of an appropriately placed tracheal tube, it is too dangerous not to remove a tube if placement cannot reliably be ascertained. In the interest of improving patient safety during emergency airway management we encourage all emergency physicians to read and be familiar with the PUMA guidelines on the prevention of unrecognized esophageal intubation.[8]

AUTHOR CONTRIBUTIONS

John C. Sakles, Christopher Ross. and George Kovacs contributed to the concept and development of this manuscript.

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