PREVENTING THE PREVENTABLE

Overcoming Barriers to Using Capnography and Pulse Oximetry During Airway Management

Prepared by Medtronic EMS Advisory Board

INTRODUCTION

In 2013, a 13-year-old boy was involved in a skateboarding accident in North Carolina.[1] He went to a local hospital, where a CT scan found no signs of bleeding, but doctors suspected a skull fracture and transferred him to a trauma center. Prior to putting him into the ambulance, they sedated and intubated him. En route to the hospital, according to a lawsuit filed by his family, the sedation wore off and he woke up. He pulled out his tube and had to be restrained by the paramedic, nurse, EMT, and respiratory therapist in the ambulance. They administered sedatives and paralytics, and reintubated him.

They did not, however, use end-tidal carbon dioxide ($etCO_2$) monitoring to confirm tube placement or continuously monitor his airway. As his oxygen saturation levels decreased and his heart stopped beating, they never discovered the tube was in his esophagus, effectively cutting off his air and oxygen supply. Doctors later discovered the problem and reintubated. He regained a pulse and his oxygen saturation levels immediately returned to normal. But by then it was too late. He had gone too long without oxygen and it was determined he had no brain activity. Life support was withdrawn and he died soon after.

Better monitoring of airways with continuous capnography and pulse oximetry can help prevent more cases like this.[2]

THE PROBLEM

The importance of monitoring a patient's respiratory status during emergent airway management cannot be overstated. Use of continuous waveform capnography and pulse oximetry can prevent adverse events and death.[2] Increased monitoring may be even more important in the prehospital or emergency department settings, where care providers face chaotic environments and multiple distractions.[3] Continuous airway monitoring is imperative during patient movement and transport, both within and outside the hospital as displaced artificial airways are most often associated with patient movement. Yet, while use of these tools has been accepted by many experts and professional societies it is our opinion that in EMS, room for improvement still remains.

Most EMS agencies that perform endotracheal intubation are now using waveform capnography, although the exact proportion is unknown, and some states don't require it. In addition, anecdotal reports of misplaced endotracheal tubes suggest that while the problem may be uncommon, it still exists, even when $etCO_2$ monitoring is available. The 2010 death of an 18-year-old following a motor vehicle crash was attributed to an unrecognized esophageal intubation by a flight paramedic who had access to capnography but didn't use it.[4] Other EMS media reports indicate that some agencies still don't carry waveform capnography or require its use.[5]

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When EMS providers manage an airway without continuous monitoring, they can potentially cause the patient's condition to worsen, and not even realize it. A misplaced airway or brief period of hypoxia can result in brain damage or even death. An unrecognized advanced airway misplacement or dislodgement is a "never event," an incident that is preventable and potentially has serious consequences. EMS agencies must strive to achieve 100% compliance with use of both waveform $etCO_2$ and SpO_2 monitoring during airway management.

THE CASE FOR MONITORING

Confirmation of endotracheal intubation with $etCO_2$

The critical importance of waveform capnography to confirm tube placement during endotracheal intubation (ETI) has been well established by several decades of evidence. By the 1990s, the benefits of prehospital capnography were being described in the literature. Some researchers called physical assessment alone unreliable, especially in a loud and busy prehospital setting and suggested that capnography was even more critical in the prehospital and emergency settings where ETI is performed less frequently and conditions when the tube is being inserted are often less favorable.[3]

The research has indicated that waveform capnography is the most effective method available to confirm tracheal tube placement during ETI attempts. Compared to other methods (including physical exam, colorimetric CO_2 detectors, and capnometry), waveform capnography has frequently demonstrated nearly 100% specificity and sensitivity, even in cardiac arrest.[6] Continuous waveform capnography also provides the benefit of providing immediate feedback that a tube has become dislodged. Other methods are often only adequate for determining initial placement.[7]

While the number of prehospital unrecognized esophageal intubations is unknown, the use of capnography has likely led to a decrease in most systems. Prior to widespread use of waveform capnography, estimates ranged as high as 25%.[8] Early studies of waveform capnography suggested that its use in the prehospital setting made attaining a rate of zero unrecognized misplaced tubes a possibility.[9] As early as 1999, the National Association of EMS Physicians (NAEMSP) recommended the measurement of $etCO_2$ as the best method for confirming ETI and suggested that capnography "may be superior to other colorimetric methods."[10]

Supraglottic airways

Continuous $etCO_2$ monitoring is often considered a domain of advanced life support (ALS) providers and, in many EMS systems, use is required for endotracheal intubation. While many states and local EMS authorities allow use of supraglottic airways by basic life support (BLS) providers during cardiac arrest, few require waveform capnography despite its inclusion in the EMS Educational Standards for BLS providers. An SGA can be misplaced, become blocked or dislodge, leading to inadequate ventilation.[11] In a study comparing paramedic assessments of SGA placement to $etCO_2$ confirmation, researchers found an unrecognized failed airway rate of 15%.[12] These studies indicate that $etCO_2$ monitoring has equal utility in the placement of SGAs as with ETI to ensure correct placement and prevent unrecognized dislodgement.

Guiding ventilation

In addition to confirmation of ETI and SGA placement, waveform capnography plays an important role in guiding ventilations. Whether attached to an advanced airway or used with bag-valve-mask ventilation, capnography readily identifies hyper- and hypoventilation. Excessive ventilation of the patient with respiratory compromise, whether a victim of cardiac arrest, head trauma, or other etiologies, is believed to be a cause of poor outcomes.[13,14] Waveform capnography provides real-time feedback of the ventilation rate and depth that can help both BLS and ALS providers optimally manage assisted ventilation in any patient.

Cardiac arrest

A large body of evidence shows that $etCO_2$ levels serve not only to confirm initial and continued proper placement of an advanced airway but also serve to monitor effectiveness of CPR and predict return of spontaneous circulation (ROSC).[15] The 2015 American Heart Association guidelines for resuscitation also recommend using $etCO_2$ levels to aid in decisions to terminate resuscitation.[16] Since many cardiac arrests are managed using supraglottic airways (one study of Resuscitation Outcomes Consortium data indicated 18.8%)[17] and not ETI, waveform capnography should not be limited to only intubated patients.

Pulse oximetry plays a vital role

Pulse oximetry assesses oxygenation, not ventilation, but is still critical during airway management. Perhaps most importantly, pulse oximetry monitoring is a critical step while preparing for and performing ETI in a patient with a pulse.

Desaturation prior to and during intubation attempts has been associated with dysrhythmias, hemodynamic decompensation, hypoxic brain injury, and cardiac arrest.[18] In studies in both the emergency department and prehospital settings, physicians and paramedics reported lower rates of desaturation during rapid sequence intubation (RSI) than those found during analysis of recorded continuous SpO_2 levels — meaning providers were likely missing episodes of desaturation or failing to document them.[18,19] Because of these risks, continuous monitoring of SpO_2 levels is critical.

Risk management

The benefits to patients are clear. But the benefit to EMS systems and practitioners goes beyond improving patient care. In the 1980s, anesthesiologists represented 3% of physicians and were responsible for 11% of malpractice award dollars paid. The American Society of Anesthesiologists (ASA) closed claims project has led anesthesiologists to enjoy some of the lowest malpractice premiums and awards today, thanks in large part to required use of pulse oximetry and capnography.[2,20,21]

Studies of airway management complications and failures in multiple other countries have also concluded that capnography and pulse oximetry are important patient safety and risk reduction tools.[22] While published studies are limited, the few EMS claims analyses that have been published show that EMS airway management cases, particularly missed esophageal intubations, are some of the most successful and costly claims.[23]

MEASURE WHAT MATTERS

With the evidence clearly showing that continuous monitoring of $etCO_2$ and SpO_2 can improve airway management and patient outcomes, it's critical that quality management programs measure and track their use. High-performance EMS systems monitor and measure whether their providers are consistently and properly assessing continuous $etCO_2$ and SpO_2 levels and using them to guide care. In addition, recording these vital signs in patient records allows for evaluation of other care processes and outcomes.

What to measure

The only way to know whether your organization is providing the best care is to measure it. But the question is what should be measured. While looking at patient outcomes is ideal, many local EMS services lack access to hospital data. Whether a system has information on patient outcomes or not, several process measures allow for robust quality assurance and improvement of airway management.

Continuous waveform capnography use

Measuring whether or not capnography is used and documented on every patient whose airway is managed with ETI, an SGA, or BVM ventilation provides assurance that caregivers are using the best tool available to evaluate the airway and avoid unrecognized esophageal intubations or other potentially deadly mistakes.

In addition to monitoring whether capnography is used, it's important to monitor whether $etCO_2$ levels were documented, as those numbers and waveforms can provide information that is vital to quality assurance, research, or legal investigations. Documentation of $etCO_2$ throughout the patient interaction, and not just for confirmation of tube placement, is also important, especially but not limited to any changes in the patient's status or location.

Intubation success rates

Some research indicates that patients who are intubated on the first attempt have fewer complications than those whose intubation requires multiple attempts.[24] For this reason, many agencies measure "first-pass rate," or the percentage of patients requiring intubation who are successfully intubated on the first attempt.

However, it's important to recognize the limits of this measure. First, an "attempt" must be defined to providers. Most researchers define an attempt as including any time the larnyngoscope blade is inserted past the teeth and into the mouth. Another limitation of this measure is the possibility that a focus to improve first-pass rates could encourage providers to spend more time on their first attempts, thus going for longer periods without ventilating the patient and leading to desaturation.[18]

SpO_2 use

One must determine if the SpO_2 is not only measured, but recorded prior to and during every airway management event where the patient has a pulse. In addition to simply measuring whether SpO_2 is recorded, some agencies are examining whether patients had any hypoxic episodes. For example, tracking whether a patient's SpO_2 levels dropped below 93% during an intubation attempt.

PERFORMANCE MEASURES

MEASURE: $etCO_2$ use

NUMERATOR: Number of patients with documented use of $etCO_2$ to confirm the tube

DENOMINATOR: Number of patients with ETI or SGA used

WHAT THIS MEANS: The percentage of patients who receive an advanced airway for whom practitioners document that capnography was used to confirm proper placement of the tube

MEASURE: $etCO_2$ value recorded

NUMERATOR: Number of patients with a documented value of $etCO_2$ levels

DENOMINATOR: Number of patients with ETI or SGA used

WHAT THIS MEANS: The percentage of patients who receive an advanced airway for whom practitioners document an $etCO_2$ value

MEASURE: Intubation first-pass rate

NUMERATOR: Number of patients for whom the first intubation attempt was documented as successful

DENOMINATOR: Number of patients on whom intubation was attempted

WHAT THIS MEANS: The percentage of patients for whom the first intubation attempt was successful

MEASURE: SpO_2 use

NUMERATOR: Number of patients for whom SpO_2 levels are documented prior to and during intubation

DENOMINATOR: Number of patients not in cardiac arrest on whom ETI was attempted

WHAT THIS MEANS: The percentage of patients with a pulse for whom SpO_2 was monitored and documented prior to and during the intubation process

MEASURE: DASH-1A (Definitive Airway Sans Hypoxia on First Attempt)

NUMERATOR: Number of patients whose SpO_2 levels do not fall below 90% during management of the airway

DENOMINATOR: Number of patients with a pulse whose are ventilated with BVM, SGA, or ETI

WHAT THIS MEANS: The percentage of patients with a pulse who did not experience hypoxemia during management of the airway

OVERCOMING BARRIERS: IMPROVING AIRWAY MONITORING

The evidence for monitoring during airway management is clear. Yet we know we need to improve. There are many reasons why EMS organizations aren't achieving their desired goals of 100% use of continuous capnography and pulse oximetry whenever managing a patient's airway. These reasons can be addressed through quality improvement efforts and other activities. Here, we address just some of the barriers preventing proper use of SpO_2 and $etCO_2$ monitoring in the prehospital environment.

Training and education

Increased training and education are needed in order to ensure that all EMS providers understand the meaning of continuous monitoring of end-tidal carbon dioxide and pulse oximetry. Currently, the National EMS Education Standards include pulse oximetry at the EMT, AEMT, and paramedic levels. However, carbon dioxide monitoring is only listed in the paramedic standards, not the EMT or even AEMT standards.[25] While some states and textbooks have added some very limited capnography training for providers at these levels, it's often aimed at providing awareness, but not a true understanding of its benefits. Yet research shows that with only some basic training on capnography, the likelihood of providers recognizing a misplaced airway increases.[26,27] At the same time, continuing education is clearly required on the topic, as some providers have overstated their understanding of capnography after initial training.[28]

Training and education should also emphasize the importance of always heeding a warning and not assuming the monitor is wrong. The use of SpO_2 and $etCO_2$ monitoring doesn't guarantee patients will be properly oxygenated and ventilated, especially when providers ignore what those vital signs are telling them. There have been documented cases of unrecognized esophageal intubations with capnography when paramedics didn't address an $etCO_2$ reading of zero.[29] It's important that EMS clinicians be aware that even when monitors alert that the condition of a patient is deteriorating, those warnings could be misinterpreted.[7] For example, if capnography doesn't show carbon dioxide waveforms following a difficult intubation, the alert might be ignored or misinterpreted that the lack of waveforms is a result of bronchospasm.[7]

Protocols

For organizations that have invested in the technology but still don't have 100% compliance, protocols are one step in ensuring the safety of patients. Many agencies may not mandate the use of continuous waveform capnography for all patients whose airways are managed with ETI or SGA. Others strongly require it. For example, Pennsylvania's statewide ALS protocols mandate any agency performing endotracheal intubation or using an alternative airway device must also use continuous waveform capnography.[30] Pennsylvania BLS protocols also direct BLS providers to notify the ALS provider in charge if there's a change in SpO_2 or $etCO_2$ levels when they're assigned to ventilate through an endotracheal tube or SGA.[31]

In Oklahoma, the EMS System for Metropolitan Oklahoma City and Tulsa reports that the system-wide, multi-agency rates of continuous waveform capnography use and documentation of such during and following intubation have remained at 100% since protocols mandated its use in July 2009. According to a communication with J.M. Goodloe (July 2016), concurrent with those protocols, the medical director instituted a 30-day suspension for any provider who didn't use and document use of continuous waveform capnography after intubation. In this same seven-year period, the EMS system has had no instances of unrecognized esophageal intubation with protocol-compliant care. Dr. Jeffrey M. Goodloe, the system's medical director, has said, "Prior to this protocol, at least some [emergency department] physicians in our EMS system's service area routinely questioned the position of endotracheal tubes placed by paramedics. No such questions remain."[32]

Crew resource management and checklists

Managing an airway is not a one-person procedure. Frequently, several team members are assisting with ventilations, monitoring the patient, administering medications, and other tasks. It could easily be the provider with the least training and least experience who is assigned the role of ventilating a patient, whether the airway is managed with BLS techniques or an advanced procedure. And in many cases, providers are distracted. Some agencies have attempted to solve this issue by assigning one provider the job of monitoring the patient's vital signs during airway management. Like the "pit-crew" approach to cardiac arrest, assigning specific roles during airway management could help reduce complications. For example, the provider-reported rate of hypoxic events during emergency intubation attempts is lower than the actual rate found by later reviews of patient records and vital signs, meaning those incidences of desaturation could be going unnoticed. Assigning someone to watch for those occurrences and to alert the rest of the team when they begin to happen could prevent further deterioration of the patient.

Checklists have also proven to be useful safety measures in the healthcare setting.[33] Applying a checklist to airway management to ensure that appropriate monitoring equipment is tested, set up, and ready could prevent mishaps such as forgetting to monitor and record SpO_2 during initial airway management or not having waveform capnography equipment prepared to be used immediately after inserting an airway device. In addition to checklists, many experts recommend a standardized equipment set-up prior to performing complex airway procedures. For example, placing $etCO_2$ monitoring equipment with ETI and SGA equipment may reduce delays in confirming device placement and ventilation.

BLS training and equipment

Because BLS providers are trained to ventilate patients with basic techniques, are sometimes authorized to use SGAs, and frequently assist ALS providers with managing airways with more advanced techniques, they should also be familiar with the basic concepts behind $etCO_2$ and SpO_2 monitoring and how to recognize airway problems in the field.

In addition, smaller, less expensive monitors can be made available for BLS providers to assess $etCO_2$ levels and waveforms along with other basic vital signs even when ALS providers are not present on the scene. The need to properly and continuously monitor patients' airways and avoid preventable deaths far outweighs the cost of monitoring $etCO_2$.

Documentation

The first step in any quality improvement process is usually improving documentation. Without adequate documentation, defining a problem is difficult. Documentation is important for data collection and analysis, as well as protection against liability. Not only is documentation important for quality assurance and legal reasons, but better documentation of ETI confirmation has also been associated with better outcomes.[34] So an improvement program aimed at enhancing the quality of documentation might also lead to better care.

Improving documentation takes a concerted effort; various methods have been attempted. In one hospital system, documentation of ETI confirmation improved after an online educational program and quality assurance review of electronic records, with email reminders sent to physicians who didn't appropriately document.[35] According to a communication with R. Maloney (June 2016), several EMS agencies use automated quality assurance programs to check electronic patient care records for documentation of capnography. Software can also be programmed to automatically require and prompt providers to input confirmation techniques whenever they document use of an advanced airway adjunct.

But the documentation of actual $etCO_2$ and SpO_2 levels and waveforms, in addition to checking the box that they were used, is becoming critical for quality improvement, research, and legal reasons. In at least one case, documentation of $etCO_2$ waveforms helped an EMS agency defend itself against accusations that its providers hadn't recognized an esophageal intubation.[5] With the ability to upload data from devices to patient care reports, EMS systems should be documenting $etCO_2$ levels and waveforms as well as SpO_2 levels and waveforms any time a patient encounter requires airway management, whether the providers are BLS or ALS.

Transfer of care

One of the most critical times for patients is the transfer of care, especially from EMS to the emergency room or trauma bay. The movement of patients and equipment creates a setting where airway equipment could be dislodged. Further movement by hospital staff could dislodge airway equipment that is then blamed on prehospital providers. For this reason, it's critical that EMS providers document the confirmation of airway placement, including $etCO_2$ values and waveforms, both before and after moving the patient to the hospital stretcher and transferring care to hospital staff. According to a communication with J.M. Goodloe (July 2016), some protocols, such as the Pennsylvania state ALS protocols, require documentation of $etCO_2$ after each movement or transfer of patient and final transfer to ED stretcher.

CONCLUSION

Evidence clearly shows the benefit of continuous monitoring of SpO_2 and waveform $etCO_2$ during prehospital airway management. Your agency may be continuously monitoring these critical vital signs during each and every incident requiring airway management. But almost certainly there's room for improvement, not only during and following intubation but especially with the growing number of patients ventilated using supraglottic airways and BLS techniques. Airway management is one of the most important interventions provided by EMS — it can save patients' lives — but it also presents an opportunity for errors with disastrous complications. Continuous capnography and pulse oximetry protect the EMS provider and the patient, making them invaluable tools in the prehospital setting.

ABOUT THE **MEDTRONIC EMS ADVISORY BOARD**

The Medtronic EMS Advisory Board is a select group of expert clinicians who have insight into the culture and mindset of the EMS and healthcare community. They include EMS medical directors, leaders, educators, and clinicians from a diverse set of EMS systems representing a wide variety of perspectives and geographies. The group will meet several times a year, addressing different clinical topics, including those related to the emerging field of mobile integrated healthcare and community paramedicine.

At their first meeting, members of the Board discussed issues related to respiratory compromise in the out-of-hospital setting. Topics included education and training, monitoring and equipment, and a range of clinical conditions. In addition, board members heard from Phillip Porte of the Respiratory Compromise Institute (RCI), who discussed the RCI's efforts to prevent avoidable deaths in the hospital.

While the Advisory Board plans to dive deeper into several topics at future meetings and in future white papers, the members agreed that addressing the problem of avoiding adverse airway events through continuous monitoring needed to be a first step. Evidence-based guidelines make it clear that these are critical patient safety issues, and several organizations recommend the use of waveform capnography in prehospital and emergency care, including the Brain Trauma Foundation, the American Heart Association, the National Association of EMS Physicians and the American College of Emergency Physicians. But it's not clear how well those guidelines are being implemented.

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