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Rationales and Applications for Capnography Monitoring During Sedation

By Devin Carr, MSN, MS, RN, RRT, ACNS-BC, NEA-BC, CPPS and Anna Cartwright, BSN, RN

In September 2011, the American Society of Anesthesiologists (ASA) approved the first substantive changes to its Standards for Basic Anesthetic Monitoring in almost a decade. Perhaps the most significant change is the recommendation for use of capnography for monitoring the adequacy of ventilation during moderate and deep sedation. The additional requirements borne by those guidelines have generated much discussion as hospitals seek to manage risks associated with anesthesia and sedation. The purpose of this paper is to describe the drivers of this change and to provide supporting evidence for use of capnography to improve quality outcomes by promoting patient safety in clinical practice.

Panel Discussion: Capnography and Conscious Sedation

Moderator: Chad Epps, MD

Panelists: Bill Ehrman MD J. Brady Scott, MSc, RRT-ACCS, FAARC

Brian Berry, MS, CRNA

In this panel discussion, 4 experts discuss the benefits of capnography to monitor various states of anesthesia during critical care. The panel addresses the consensus guidelines and statements from multiple organizations regarding monitoring of ventilation during procedural sedation and the application of those guidelines in their practice; how capnography compares to pulse oximetry and respiratory rate measurement for detecting changes in respiratory status during procedural sedation; the use of capnography in nonintubated patients; the primary barriers to implementing ventilatory monitoring during procedural sedation; capnography waveform interpretation (and the difficulty doing so among many clinicians); and finally, the use of capnography in neonatal and pediatric populations.

Rationales and Applications for Capnography Monitoring During Sedation

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In September 2011, the American Society of Anesthesiologists (ASA) approved the first substantive changes to its Standards for Basic Anesthetic Monitoring in almost a decade. Perhaps the most significant change is the recommendation for use of capnography for monitoring the adequacy of ventilation during moderate and deep sedation. The additional requirements borne by those guidelines have generated much discussion as hospitals seek to manage risks associated with anesthesia and sedation. The purpose of this paper is to describe the drivers of this change and to provide supporting evidence for use of capnography to improve quality outcomes by promoting patient safety in clinical practice.

Drivers of Change

ASA's standards are the backbone of basic anesthesia monitoring in hospitals and clinics. Those standards represent expert consensus, based on research findings and best evidence available. The most recent iteration of the standards includes the addition of capnography (end-tidal carbon dioxide [EtCO₂]) monitoring for deep and moderate sedation¹ (July 2011). By definition, standards are rules or requirements that reflect accepted practices for safe patient care. Standards set by professional organizations serve as care guidelines but not necessarily regulatory requirements. As such, healthcare practitioners and providers

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must carefully interpret standards in prioritizing which practice changes to implement.

While the benefits of capnography for confirmation of airway status and early detection of hypoventilation in the OR setting are clearly documented in the literature, much debate remains regarding its necessity during monitored anesthesia care and procedural sedation when other means of assessment are employed. Consequently, debate has arisen over the breadth of practice for EtCO₂ monitoring.

Impediments to Change

The standard of care for patients who undergo general anesthesia in hospital ORs has long included cap-

nography along with pulse oximetry. As familiar as both are in that milieu, it is still relatively foreign to think about capnography in outpatient and alternative settings such as endoscopy centers and dental clinics, as well as emergency departments and other procedural settings beyond traditional ORs.

Lack of familiarity and the greater variability of human and capital resources in non-OR settings translate to barriers to implementing ASA's latest standards. Inconsistencies in staffing levels, education levels, lack of capital funds and available training, looser oversight from hospitals or other bodies, and the relatively few studies published regarding outcomes secondary to capnography in non-OR/non-general anesthesia settings all can slow the impetus for change.

Besides the cost of basic EtCO₂ monitoring equipment (est. \$3,000–\$5,000 or more per device, plus disposable supplies), additional clinical staff and additional training may be required. In an era of increasing costs and declining reimbursements, the up-front costs could be a rate-limiting step. However, to understand the return on investment, clinicians and administrators need to fully understand the implications of not implementing the guidelines: an increased rate of adverse events (AEs) and the cost of their sequelae (extra lab tests and interventions), as well as potential litigation costs if severe harm occurs.

Evidence for increased AEs and their cost is abundant in the literature for OR scenarios. A systematic review of previously published studies² revealed that an estimated 41% of all hospital-related AEs occurred in the OR with fewer events (3.1%) occurring in the intensive care environment. Thus, despite ASA saying that capnography is now required during moderate and deep sedation, it remains a question mark in many people's minds. This creates a gap between

evidence and practice.

To address that question, two buckets of information need to be evaluated: (1) what capnography contributes to the clinical picture compared to the contributions of pulse oximetry, and (2) what the literature says about capnography in these broader settings. Understanding both will shed light on what led ASA to these recommended practice changes.

Oxygenation vs. Ventilation: Oximetry, Capnometry, Arterial Blood Gases, and Observation

Even though oxygenation and ventilation are related, they are separate physiologic processes.³ Simply put, ventilation is inhaling and exhaling, while oxygenation is the process of putting oxygen into the body. Ventilation adequacy is a precondition for oxygenation and refers to the exchange of air between the alveoli and the atmosphere. Ventilation cannot be adequately assessed simply by monitoring oxygenation.

Pulse oximetry

Pulse oximetry measures oxyhemoglobin saturation, but it cannot determine oxygen consumption or metabolism; as such, it is an incomplete measure of respiratory function. Even when combined with clinical observation, oximetry lacks the sensitivity to provide early detection of hypoventilation. Hypercarbic changes may go undetected by oximetry, at least initially, until hypoxemia—a late sign—manifests. In short, pulse oximetry provides excellent information about oxygenation, yet it fails to provide information about ventilation—and changes in O₂ saturation tend to be late signs of patient compromise. As noted by Vargo and colleagues (2002), pulse oximetry only identified 50% of events related to apnea or respiratory depression, and for those events detected by pulse oximetry, there was a delay of approximately 45.6 seconds

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(range of 15-120 seconds) following capnographic detection of respiratory depression.⁴ Continuous monitoring of exhaled CO₂ provides evidence of respiratory depression much sooner and allows the clinician to take faster corrective action.⁵

Capnography

Capnography is the direct measurement of exhaled carbon dioxide. Alterations in expired CO₂ serve as an early indicator of respiratory compromise, providing medical professionals with information about ventilation as well as oxygenation.^{6,7}

Arterial blood gases (ABGs)

ABGs measure arterial pH, oxygen and carbon dioxide tension, bicarbonate, and oxygen saturation. Because capnography determines the exhaled partial pressure of CO₂, one might think it should always correlate with the partial pressure of CO₂ obtained from an ABG. However, multiple factors can affect capnography values so that they do not appear to align with PaCO₂ values from an ABG. The capnography measurement technique (mainstream vs. sidestream) and the amount of physiologic or mechanical

dead space present must be taken into consideration if doing a side-by-side comparison. But, because EtCO₂ may seem to not measure up to an ABG value, some clinicians question the accuracy of capnography data and therefore discount the value of this ventilatory parameter.⁸

Physical assessment

While clinical observation is always a part of patient care, it does not yield information regarding respiratory sufficiency beyond what pulse oximetry and capnography can provide. For example, assessing depth of breathing as a surrogate for oxygenation is subjective. Similarly, skin color is a subjective evaluation inherently fraught with problems including skin pigmentation. It is also an unreliable predictor of cyanosis, as the skin may not show evidence of that until saturation levels are well below 80%.⁹

As with oxygenation, observational assessments have been used historically to determine respiratory rate, depth, and effort. Qualitative assessments of chest excursion and breath sounds are appropriate (though subjective) for assessing breathing effectiveness in patients undergoing regional or local anesthesia with no sedation—but not for patients receiving general anesthesia or sedation. Such assessments are not early detectors of depressed ventilatory function.

Respiratory rate (RR) alone may be one of the earlier indicators of complications, including respiratory acidosis, and may signal the onset of a crisis. However, research shows that observational RR is measured improperly. Clinicians often assess RR for only 15 or 30 seconds, then extrapolate a full minute. Also, studies have demonstrated that manual RR may be a best guess rather than a precise measurement.¹⁰ Capnography includes automated RR readouts.

In a final comparative note, patients receiving continuous capnogra-

phy monitoring demonstrate a significantly higher rate of hypoventilation compared to patients who receive traditional monitoring with pulse oximetry combined with routine vital sign monitoring and patient assessment. This further suggests a high rate of unrecognized respiratory depression.⁸

What the Literature Says about Capnography in Traditional ORs and Beyond. Where it started: in the OR

Over the past two decades, end-tidal carbon dioxide monitoring has emerged as a standard for intra-operative monitoring for patients undergoing general anesthesia.¹¹ Studies have documented the contribution of capnography in the operating room. Specifically, Brown (1992) studied the utility of capnography in detecting anesthesia-related events using a retrospective cohort design.¹² Findings suggested that EtCO₂ was instrumental in confirming suspected events in 58% of documented complications and was the initial detector of 27% of all documented anesthesia-related adverse events. Benefits of capnography in the OR include confirmation of endotracheal tube placement, guidance of ventilation parameters, and early detection and diagnosis of hypoventilation.

Beyond the OR

Today, many procedures which were once performed in the operating room using rigorous standards for physiological monitoring are performed outside of the OR. Unfortunately, as noted by Galvagno and Kodali (2009), the monitoring standards for these remote locations have not conformed to the standards in place in the OR setting.¹¹ Several reasons for this discrepancy in practice are noted and include lack of anesthesiologist participation in planning for out of OR procedures as well as medical proceduralists who may be unfamiliar

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with monitoring standards that are mandated in the OR.

A meta-analysis conducted by the University of Alabama demonstrated that capnography was a valuable addition to standard pulse oximetry in identifying respiratory depression during procedural sedation. Reviewing studies published between 1995 and 2009, researchers analyzed adverse respiratory events reported during procedural sedation and analgesia when clearly defined end-tidal carbon dioxide thresholds were present. Five studies were included in the analysis; results indicated that respiratory events were 17.6 times more likely to be detected correctly with capnography.¹³

Studies of capnography use in venues such as gastroenterology, emergency medicine, and pediatrics remain limited. The paucity of research to date on capnography in those arenas has led some to question the broad applicability of capnography across diverse patient settings and

populations. However, the studies that do exist show the benefits of capnography—and the dangers of not using it—in those settings.

Fanning's 2008 "snapshot audit" underscored the dangers. This survey of non-anesthetic doctors showed that minimal monitoring requirements were not always in place. Procedures performed included endoscopies, interventional cardiology and radiology. Notably, (1) capnography was never used, and (2) incidences of hypoxia and respiratory depression far outstripped all other adverse events. Twenty-two percent of the doctors reported that they had treated a patient with an adverse event.¹⁴

On the flip side, a 2006 study on the use of capnography during endoscopies on pediatric patients showed that fewer respiratory events occurred when capnography prompted early intervention, even in the absence of other clinical indicators.¹⁵ Similarly, a 2010 randomized controlled study in an emergency department exhibited a 17% decrease in hypoxic events by utilizing capnography during procedural sedation.¹⁶ The ColoCap study (2012) conducted in German endoscopy centers showed that ventilation changes (apnea, hypoxemia) were detected far more often in colonoscopy patients by using capnography compared to standard monitoring (pulse oximetry + blood pressure + EKG).¹⁷ As Beitz noted in the 2012 study, these findings have broad applicability because colonoscopy is one of the most common invasive GI procedures performed.

There is widespread agreement that improved monitoring and awareness of cardiorespiratory status yields better outcomes. Additionally, an emerging body of evidence indicates that broader use of capnography is warranted. Agencies such as The Joint Commission, the American Society of Anesthesiologists, the Institute for Safe Medication Practices, the Anesthesia Patient Safety Foundation, and

the American Heart Association all recommend capnography as an early detection strategy to improve patient safety and yield quality outcomes.¹⁸ Despite all that, some professional organizations affected by the latest ASA guidelines do not subscribe to the need for capnography during moderate and deep sedation and have reflected that sentiment in an official statement.¹⁹

Old Habits Die Hard

Since the 1990s, the gold standard for respiratory monitoring, particularly during anesthesia, has been pulse oximetry. Pulse oximetry measures oxygenation but fails to provide information about ventilation—and changes in oxygen saturation tend to be late signs of patient compromise with oximetric changes manifesting approximately 45 seconds after changes in ventilation occur.⁴ Despite its inability to assess ventilation status, oximetry's popularity, ease of use, and broad applicability earned it a nod from at least one author as

“the most important technological advance ever made in monitoring the well-being and safety of patients during anesthesia, recovery, and critical care.”⁹ While that pronouncement could be challenged, Severinghaus (2011) further noted that pulse oximetry monitoring has been associated with a ten-fold reduction in deaths attributed to anesthesia. Interestingly, multiple double-blind studies (total $n = 23,000$) have failed to demonstrate a direct relationship between pulse oximetry and adverse outcomes when clinicians were unaware of SpO_2 values during anesthesia.

Optimal Patient Monitoring

Non-anesthesia providers in diverse procedural settings may be less likely to adhere to the new guidelines or facility protocols than those who work in the more highly scrutinized inpatient OR settings. This is evidenced by studies showing a higher incidence of respiratory depression and desaturation events as the number of procedures performed outside

the OR has increased. However, an increasing number of people needing those procedures are patients with multiple comorbidities and complex care needs. We can expect that to increase as America ages. Today one in seven Americans is age 65 or older. By 2030, it will be one in five—and most of them will have multiple chronic conditions.²⁰ An aging America plus increasingly more care being pushed out from acute care settings to other venues increases the need for adequate respiratory monitoring during procedures.

ASA's latest guidelines propel capnography into broader usage with more diverse patient populations. Even so, the proposed benefits of capnography extend far beyond operating rooms and procedural areas. Because measuring exhaled CO_2 provides the earliest possible detection of respiratory depression, this mode of patient monitoring has even wider applicability. Capnography has been demonstrated to detect sudden-onset respiratory failure, respiratory depression for patients receiving opioid analgesics, and even undiagnosed obstructive sleep apnea. Due to its perceived benefits in those patients, and, in the interest of patient safety, many institutions have incorporated capnography into routine monitoring for patients at high risk for respiratory complications.¹⁸

Implementing the 2011 ASA Guidelines

Prior to the 2011 guidelines, capnography was optional during moderate and deep sedation as long as other methods of assessing ventilation were utilized. The new guidelines, which include specifics regarding both, create resource challenges as many procedural areas attempt to implement $EtCO_2$ monitoring. But guidelines form the basis of facility protocols, and guidelines often evolve into regulations; so it is pru-



The ASA recommends patient monitoring of CO_2 during moderate or deep sedation. The use of a proprietary Sampling Cannula allows delivery of supplemental oxygen while simultaneously sampling expired CO_2 (Courtesy of Teleflex Incorporated).

dent to implement today what may be mandated tomorrow.

However, even the best protocols are subject to individual practice decisions and inconsistent compliance. Beyond capnography itself, adequate knowledge and training in the practices of sedation and anesthesia have been found to vary widely, as noted in Fanning's 2008 study.¹⁴ That poses significant patient risk. For example, delivering standard bolus volumes instead of weight-based dosing regimens is both a protocol issue as well as an individual preference. The Fanning study highlighted such variations in practice despite the presence of guidelines and protocols.

To ensure optimal compliance with protocols for monitoring patients during anesthesia and sedation, healthcare facilities can benefit from policies that guide the safe administration of anesthesia and sedation. Such policies should include roles and responsibilities for providers, processes by which providers are credentialed to provide care, a list of suggested medications with suggested doses, and appropriate methods of patient monitoring.²¹

Summary

Clinicians and researchers consistently agree that capnography provides useful clinical information while reducing the incidence of hypoxic and/or hypercarbic events during anesthesia and sedation.²² It is essential that patients receive optimal monitoring to detect early signs of impaired ventilation and/or oxygenation. This is universally true, but the paradigms applying to monitoring during anesthesia versus moderate/deep sedation differed in the past. Now that they are on equal footing, it is important to know why. Anesthesia and sedation are associated with known risks, particularly in elderly patients and those with multiple comorbidities—which

further supports the wider use of capnography. Capnography provides real-time, quantitative assessment of oxygenation and ventilation and can alert clinicians to early changes before hypoventilation or hypoxia occurs. There is demonstrated value to enhanced monitoring, which combines oximetry and capnography; that value is reflected in the 2011 ASA guidelines. The ASA guidelines provide a safety net of safer patient monitoring practices during administration of anesthetic and sedative agents.

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Panel Discussion: Capnography and Conscious Sedation

Moderator: Chad Epps, MD

Panelists: Bill Ehrman, MD

Jonathan Scott, RRT

Brian Berry, MS, CRNA

Multiple organizations have released consensus guidelines and statements regarding monitoring of ventilation during procedural sedation. What standards of practice do you use for capnography in that arena?

EHRMAN: Our practice is guided by the current ASA recommendations.¹ We utilize end-tidal carbon dioxide monitoring during any procedure in which moderate or deep sedation is indicated; for example, to avoid significant patient discomfort during colonoscopies and endoscopies. While deeper sedation improves patient satisfaction and the gastroenterologist's ability to perform the procedure,² the short-acting agent propofol is being used more widely for procedural sedation. That introduces increased risk of hypoventilation, apnea, aspiration, airway obstruction and cardiovascular instability. Capnography detects those changes earlier, which improves patient monitoring and safety. We also utilize capnography during procedures requiring mild sedation, such as cataract surgery. Even then, patients with comorbidities such as obstructive sleep apnea have the potential to obstruct. Therefore, with consistent use of capnography, patient safety is improved.

We utilize end-tidal carbon dioxide monitoring during any procedure in which moderate or deep sedation is indicated.

- Ehrman -

BERRY: According to the Institute for Safe Medication Practices³ and the Anesthesia Patient Safety Foundation,⁴ all healthcare professionals should use technology equipped to estimate carbon dioxide in the blood. Implementing those guidelines ensures safe, effective procedural sedation for patients. During procedural sedation, SpO₂ monitoring lags behind capnography cessation alarms. Capnography is a more sensitive indicator of respira-

tory distress.

SCOTT: In addition to those organizations, the American Society of Anesthesiologists and the American College of Emergency Physicians both recommend the use of capnography during procedural sedation to monitor ventilation adequacy.^{5,6} Both organizations clearly acknowledge the benefits of capnography as an adjunct to standard clinical assessment and other tools such as pulse oximetry.

For anyone providing procedural sedation, it is imperative to detect changes in respiratory status as early as possible. How does capnography compare to pulse oximetry and respiratory rate measurement for detecting changes in respiratory status during procedural sedation?

EHRMAN: First off, capnography assesses ventilation; pulse oximetry and respiratory rate (RR) do not. Beyond that basic difference, the changes in a patient's respiratory status can be detected much earlier with continuous capnography than with pulse oximetry and RR measurements. Burton et al. showed that minutes can pass in a patient who is apneic or hypoventilating prior to development of hypoxia that can be detected by means other than capnography.⁷ In fact, Burton's study was stopped sooner than anticipated when an independent review showed that capnography detected 20 acute respiratory events in 60 patient sedation encounters—most of which had EtCO₂ abnormalities that occurred before hypoxia could be detected clinically or by pulse oximetry.

Continuous pulse oximetry has its place. It assesses a patient's oxygenation, but there can be a significant delay in detecting desaturation during apnea, obstruction, or hypoventilation. When looking at the oxygen-hemoglobin dissociation curve, once a patient's partial pressure of blood oxygen decreases to a certain point, the amount of oxygenated hemoglobin declines even more rapidly—giving the anesthesiologist less time to provide sufficient oxygenation and ventilation. With the use of capnography, ventilatory changes are detected earlier, giving the anesthesiologist more time to manage the patient's airway.

Similar concerns exist with RR monitors, such as impedance pneumographs and pressure-sensitive pads. They can fail to alarm in the presence of apnea and obstruction because of interference from paradoxical chest wall movements, artifacts from patient movement and even the patient's heartbeat.

BERRY: A recent study in *Anesthesia & Analgesia* also graphically described the sensitivity of capnography compared to pulse oximetry.⁸ Patients monitored by capnography demonstrated respiratory depression 58% of the time. Based on pulse oximetry readings alone, only 12% of the patients would have been detected as having respiratory depression. Furthermore, when using supplemental oxygen, studies suggest that pulse oximetry does not provide clinically effective data. The Joint Commission Sentinel Event #49 clearly states that healthcare providers should not rely solely on SpO₂ when using supplemental oxygen, but instead employ continuous capnography.⁹ I've personally seen pulse oximetry remain at 100% while the patient's capnography waveform was absent for several seconds. Unfortunately, those seconds can become dangerous as obstruc-

So I recommend that all healthcare professionals use capnography during procedural sedation for the most up-to-date, safe, and sensitive monitoring

- Berry -

tion begins, leading to hypoxia and ultimately cardiopulmonary arrest. So I recommend that all healthcare professionals use capnography during procedural sedation for the most up-to-date, safe, and sensitive monitoring.

SCOTT: The greater sensitivity of capnography has been widely published and is easy to illustrate in the laboratory and classroom settings. For example, Miner et al. reported that, during procedural sedation and analgesia in the emergency department, capnography could detect respiratory depression, independent of pulse oximetry.¹⁰⁻¹² Anderson's study of capnography during pediatric orthopedic procedures showed that it detected apnea in all cases before pulse oximetry did.¹³ In the classroom, I teach the limitations of pulse oximetry and the real-time feedback of capnography by putting myself on the devices and holding my breath to mimic apnea. The students gain an appreciation for the breath-to-breath analysis of respiratory status. They can see that someone can be apneic for a time with no

measurable changes in heart rate and pulse oximetry.

Accurate breath sampling is critical in assessing ventilation for patients undergoing procedural sedation. Breath sampling is historically less accurate for the non-intubated patient. What is your experience using capnography in non-intubated patients, and has recent technology enhanced your ability to do this accurately?

EHRMAN: Accuracy is a relative term when discussing breath sampling. Quantitatively speaking, the ET_{CO₂} measured with capnography is more accurate when the patient is intubated because there is less dilution of CO₂ with non-pulmonary gases [room air, dead-space gases]. However, the exact end-tidal CO₂ concentration is not the purpose of capnography during procedural sedation—the qualitative graphic visualization of ventilation and respiratory rate to detect early apnea and obstruction is the impetus for capnography during procedural sedation.

SCOTT: Most of my experience using capnography in non-intubated patients is in the emergency department. While there are some occasions when the waveform or numeric display is less than stellar, overall I find it works nicely. A while back, providing supplemental oxygen posed some challenges, as the flow seemed to distort the readout. That issue was alleviated by newer cannulas that allow for simultaneous oxygen delivery and carbon dioxide sampling. Another problem occurred when patients directed airflow from the nose to the mouth. Again, improved cannulas reduced that issue by sampling both from the nose and over the mouth.

BERRY: Agreed. The latest capnography technology can indicate the patient's quality of breath, respiratory

rate, amount of CO₂, and if the patient stops breathing.¹⁴ When using the best products available, health-care professionals can expect to see accurate morphology of the capnography waveform in sedated patients. Conversely, using older technology can generate skewed results or poor morphology of capnogram waveforms.¹⁵

EHRMAN: Yes, technology is definitely catching up with expanding needs. And today's technology is much more accessible. Less bulky, more readily transportable capnography machines make monitoring in off-site procedure areas more reasonable.

SCOTT: Ultimately, the clinician must be savvy in interpreting capnography results. Like any device, the monitor's information must be taken into context of the clinical situation. A slightly distorted waveform that reveals a normal breathing rate/ pattern, coupled with normal pulse oximetry and other physiologic measures, may still add the clinical confidence needed to continue with the procedure. Capnography is not without limitations, but advancements in the technology have certainly improved it over time.

In 2011, The American Society of Anesthesiology revised its Standards for Basic Anesthetic Monitoring to include monitoring of ventilation by capnography during procedural sedation. Even so, many institutions and providers are not routinely doing this. What do you think are the primary barriers to implementing ventilatory monitoring during procedural sedation?

EHRMAN: I believe the most common barrier is the additional cost, especially for offsite procedure locations [ERs; MRI/CT, GI and cath labs; outpatient centers]. The cost for the machine, sample tubing and

...newer cannulas are available that allow for simultaneous oxygen delivery and carbon dioxide sampling.

- Scott -

sampling nasal cannulas can be a significant financial burden, especially in small, independent institutions. Another reason for not routinely using capnography is a lack of education about the new ASA guidelines for moderate and deep sedation. Finally, anesthesia providers have been performing sedation procedures for decades without using end-tidal carbon dioxide monitoring, so a certain comfort level has developed amongst that generation of providers to use sedation without this technology.

BERRY: Simply put, the barriers are the institution and logistics. Hospitals fear that the cost of providing capnography will drastically increase expenditures. However, studies disprove that. In fact, the benefits significantly outweigh the risks. If, for example, a patient does have a respiratory complication, the cost to treat that patient will be substantially higher than providing the basic monitor.¹⁶ Conversely, many health care organizations understand that capnography monitoring is warranted but cannot ensure that all facility locations are equipped to actually utilize capnography. Once a hospital declares it will monitor capnography during sedation, all locations where sedation is

given must adhere to the guideline. Hopefully additional studies will clearly demonstrate the economics of patient safety as being much more important than the minimal cost of the technology. Many hospitals will need time to implement this endeavor due to the many layers of approvals.

SCOTT: Even though pulse oximetry is used widely as an exclusive monitor for oxygen and ventilation,¹⁷ although its is an off-label use in respect to ventilation. Still, the reality is that pulse oximetry is easy to use, readily available and usually simple to interpret. With new technology like capnography comes additional training needs, including initial training and ongoing annual competencies. All of that, coupled with the overall lack of evidence regarding outcomes, may pose barriers in many institutions.

The literature suggests substantial limitations in healthcare providers' abilities to accurately interpret capnography waveforms. Even with substantial training, this sometimes remains an issue for non-anesthesiologists providing procedural sedation. Why do you think this is, and what are possible solutions?

EHRMAN: Again, interpreting capnography waveform shape is not the purpose of EtCO₂ monitoring during procedural sedation. Under general anesthesia, with an endotracheal tube in place, waveform interpretation can be important in diagnosing bronchospasm, pulmonary embolism and hypermetabolic states such as malignant hyperthermia and thyrotoxicosis. During procedural sedation, the goal is to monitor whether or not the patient has sufficient gas exchange—and to detect apnea and obstruction quicker than pulse oximetry, RR monitors or visual clinical changes [chest-wall movement and

facemask humidification] can. Teaching non-anesthesiologists to detect the presence or absence of a waveform on a screen should not be an issue. Interpreting capnography waveforms in great detail is not necessary. The goal of capnography during procedural sedation is to monitor whether or not a waveform is present, the frequency of the waveform and possibly any change in waveform amplitude, which would alert the provider to any signs of respiratory depression.

BERRY: I believe that many non-anesthesia providers have not been educated properly in capnography. This is probably due to inadequate exposure to the latest advances in monitoring standards. Departments should provide in-services that explain the patient safety benefits of capnography. Specifically, hospitals are responsible for instruction on how to interpret the capnography waveform in terms of morphology, quality of breathing, respiratory rate, EtCO₂ values, obstruction, and apnea. Finally, staff should be able to demonstrate the ability to understand capnography by written or oral examination. I'm optimistic that institutions will begin to implement capnography lectures so healthcare professionals are up to date on the latest trends of procedural sedation as well as current monitoring guidelines.

SCOTT: Proficiency often follows training and repetition. In medical education using high-fidelity simulations, repetitive practice enhances skill achievement and maintenance.¹⁸ Ditto for clinical skills being enhanced by repetitive clinical practice. Unfortunately, non-anesthesia providers may be tasked with conscious sedation procedures only on a limited basis, which could result in an inadequate understanding of the technology. Solutions to this issue could include increasing training frequency for current staff or

utilizing staff (like respiratory therapists) that use capnography regularly. Uses range from cardiac arrest situations, such as evaluating adequacy of chest compressions/return of spontaneous circulation, to trending of mechanically ventilated patients over time. It is respiratory therapist's duty to analyze and interpret the results to make timely interventions. Unfortunately, staffing demands may prevent respiratory therapists from being available in all clinical areas. However, if they are available, their skill set may meet this need.¹⁹

Neonatal and pediatric populations present unique challenges for utilizing capnography in procedural sedation. Can capnography be utilized reliably in all patient populations?

EHRMAN: Lightdale's study of non-intubated children receiving moderate sedation for nonsurgical procedures demonstrated that capnography does alert the provider earlier of alveolar hypoventilation and does reduce arterial hypoxemia in pediatric patients during procedures requiring moderate sedation.²⁰

SCOTT: Even before Lightdale, more than 14 years ago, capnography was shown to be useful in the pediatric population.²¹

EHRMAN: Even though neonatal and pediatric patients desaturate much more quickly than adult patients, capnography still detects apnea and obstruction earlier than pulse oximetry. Because neonates and infants have a lower functional residual capacity, fewer functional alveoli and increased oxygen consumption, the time from apnea or obstruction to desaturation is much shorter. Therefore, earlier detection of the pediatric patient's ventilatory status is even more critical—and capnography is the fast-

est method to detect such changes. Better monitoring of pediatric patients improves their standard of care.

SCOTT: Currently, pediatric masks and cannulas can simultaneously provide supplemental oxygen and sample carbon dioxide. If the patient is somewhat compliant and the equipment is properly applied, I find capnography to be reliable in pediatric patients.

BERRY: As healthcare professionals, we are expected to deliver the safest care possible. As already noted, pediatric patients can deteriorate rapidly due to their higher oxygen consumption.²² I believe that pediatric societies will follow other organizations that have already issued position statements about capnography monitoring. More research will help expedite that.

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Questions

1. Capnography provides earlier detection of hypoventilation than pulse oximetry?
 - A True
 - B False
2. The 2011 changes to ASA Standards for Basic Anesthetic Monitoring suggested the addition of which of the following during moderate and deep sedation?
 - A continuous pulse oximetry monitoring
 - B frequent assessment of rate and depth of respirations
 - C capnography
 - D continuous ECG monitoring
3. All of the following represents additional benefits of capnographic monitoring in the OR setting EXCEPT?
 - A precise measurement of oxygenation status
 - B detection of more hypoventilation than pulse oximetry alone
 - C earlier detection of hypoventilation
 - D confirmation of airway status
4. Newer uses of capnography include the detection of respiratory depression in patients receiving opioid analgesics as inpatients.
 - A True
 - B False
5. All of the following have impeded capnography from broad use outside the operating room EXCEPT
 - A cost of equipment
 - B limited research on outcomes in procedural areas
 - C lack of familiarity in outpatient and alternative settings
 - D increasingly complex health status of Americans
6. Detection of respiratory depression using pulse oximetry alone may be delayed by an average time of _____ following capnographic detection.
 - A 5 seconds
 - B 45 seconds
 - C 3 minutes
 - D 5 minutes
7. Capnography provides clinicians with a better picture of both ventilation and oxygenation.
 - A True
 - B False
8. Which of the following are true regarding clinician assessment of respiratory rate?
 - A observational RR is often measured improperly
 - B clinicians only assess for 15-30 seconds then extrapolate rate per minute
 - C studies have demonstrated that measurement of RR is often a best guess
 - D all of the above
9. Which of the following is a primary benefit of using capnography for procedural sedation?
 - A shorter recovery period for the patient
 - B early detection of complications leading to early intervention
 - C lower sedation dose required
 - D decreased risk of procedural complications
10. To ensure patient safety and compliance with best practices, health care facilities should have which of the following measures in place for patients undergoing anesthesia and sedation?
 - A policies to guide the safe administration of anesthesia/sedation
 - B clearly defined roles and responsibilities for providers
 - C appropriate methods for patient monitoring
 - D all of the above

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2. Indicate to what degree the program met the objectives:

Objectives

Upon completion of the course, the reader was able to:

1. Explore drivers of change for basic anesthetic monitoring.

Strongly Agree	Strongly Disagree
1 2 3 4 5 6	1 2 3 4 5 6
2. Discuss capnography as a strategy for promotion of patient safety.

Strongly Agree	Strongly Disagree
1 2 3 4 5 6	1 2 3 4 5 6
3. Evaluate barriers to implementation of capnographic monitoring

Strongly Agree	Strongly Disagree
1 2 3 4 5 6	1 2 3 4 5 6
4. Please indicate your agreement with the following statement. "The content of this course was presented without bias toward any product or drug."

Strongly Agree	Strongly Disagree
1 2 3 4 5 6	1 2 3 4 5 6

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| 2 | A B C D | 7 | A B C D |
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