



Review of Capnography for Basic Anesthetic Monitoring

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Introduction

The American Society of Anesthesiologists (ASA) updated the Standards for Basic Anesthetic Monitoring, requiring the use of capnography during moderate sedation. On 01 July 2011, the implementation of these new changes was placed into effect. Capnography is defined as the noninvasive infrared measurement and display of the partial pressure of carbon dioxide (CO₂) during a respiratory cycle.¹ This display, or capnogram, usually consists of the maximum inspiratory and expiratory concentrations of CO₂ plotted against time; resulting in a CO₂ concentration waveform.² Essentially, this waveform directly reflects the amount of CO₂ eliminated by the lungs. Hypoxia, a condition in which the body is deprived of an adequate supply of oxygen, is certainly a primary concern during all anesthesia procedures. Perhaps the greatest asset of capnography during anesthetic monitoring is the early identification of potential situations which can result in hypoxia.³ The objective of this clinical update is to review capnography and its role in basic anesthetic monitoring.

Capnogram

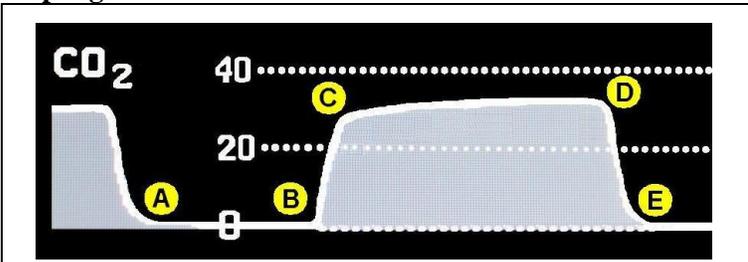


Figure 1. This carbon dioxide waveform, or capnogram, reflects the concentration of partial pressure CO₂ during a respiratory cycle. Expiration occurs along points A to D as follows: A-B is exhalation of anatomic dead space; B-C is a sharp upstroke characteristic of exhalation of the lower airway; and C-D reflects the exhalation of the alveoli. ETCO₂ is recorded at point D. Inspiration occurs along points D-E.^{1,4}

Regulations and Guidelines

The Standards for Basic Anesthetic Monitoring apply to all general anesthetics, regional anesthetics and monitored anesthesia care. An outline of the ASA standards pertinent to this clinical update follows. Standard 2: During all anesthetics, the patient's oxygenation, ventilation, circulation and temperature shall be continually evaluated. Standard 3 (Ventilation): Ensures adequate ventilation of the patient during all anesthetics using a variety of methods. In this standard, section 3.2.4 was changed to read "During regional anesthesia (with no sedation) or local anesthesia (with no sedation), the adequacy of ventilation shall be evaluated by continual observation of

qualitative clinical signs. During moderate or deep sedation the adequacy of ventilation shall be evaluated by continual observation of qualitative clinical signs and monitoring for the presence of exhaled carbon dioxide unless precluded or invalidated by the nature of the patient, procedure, or equipment."⁵ Capnography's role in the current Standards for Conduct of Moderate and Deep Sedation are defined by the Bureau of Medicine and Surgery instruction (BUMEDINST) 6710.67B. These standards clearly illustrate this monitor's potentially additive benefit to patient safety. The BUMEDINST 6710.67B states: "When ventilation cannot be directly observed, capnography may be useful" and during all deep sedation: "The use of continuous capnography is highly recommended."⁶

Understanding Capnography

Understanding capnography and its limitations are essential for the early detection of many respiratory complications. Figure 1 illustrates and explains the ideal carbon dioxide waveform and the four characteristic phases of a capnogram. The purest measure of adequate patient ventilation is by the continuous assessment of CO₂ levels in arterial blood. Due to impracticality in the outpatient dental setting, the level of CO₂ at the end of tidal expiration (ETCO₂) is used as a close approximation to the aforementioned invasive blood gas measurement. This end tidal assessment is the basis for capnography. While the normal partial pressure of CO₂ in arterial blood (PaCO₂) is approximately 40 mm Hg, the normal ETCO₂ is approximately 35-38 mm Hg.⁴ The underestimation of the PaCO₂ has been extensively documented in the anesthesia literature, ranging from 3.5 to 4.6 mm Hg.^{7,8} It is important to realize the potential limitations of using nasal cannula sampling capnography during moderate and deep sedation. Capnograms obtained during this type of sedation may not be as ideally depicted as those obtained in intubated patients.³ Abnormal or inaccurate waveforms have been attributed to the difficulty in obtaining end tidal gases and cannula obstruction. Although not substantiated in the literature, the addition of supplemental oxygen through the sampling nasal cannula has been attributed to inaccurate waveform potential.⁹ Raheem showed that spontaneously breathing, non-intubated patients receiving supplemental oxygen through a balloon-tipped nasal catheter had ETCO₂ levels well within the normal corresponding range of PaCO₂ levels.¹⁰ If needed, adjunctive devices can be utilized to improve sampling. To further maximize the effectiveness of capnography and surmount inaccuracies during basic anesthesia monitoring, providers should focus attention to any changes from the patient's baseline capnogram and ETCO₂ values instead of monitoring differences noted from

the ideal CO₂ waveform. Therefore, any changes observed from the baseline values may be attributed to depression of ventilation or airway obstruction, until otherwise proven by close examination.³ With proper identification, complete understanding, and taking appropriate pre-anesthesia measures, providers can certainly minimize the potential for these abnormal waveforms and maximize patient safety.

Evidence Based Literature

In a randomized, blinded study, Deitch evaluated 132 patients receiving supplemental oxygen during procedural sedation with propofol in the emergency department. Hypoxia, defined in this study as an oxyhemoglobin saturation with a pulse oximeter (SpO₂) of < 93%, was observed in 67% of patients and capnography successfully identified all of these cases before onset! The mean time from capnographic evidence of respiratory depression to hypoxia was 60 seconds. It was concluded that the addition of capnography to standard monitoring reduced hypoxia and provided advanced warning for all respiratory depression events.¹¹ Vargo verified that during upper endoscopies capnography is an excellent indicator of respiratory rate. Furthermore, 54 episodes of apnea or hypoventilation occurred with a mean duration of 71 seconds, yet only 50% of these episodes were detected by pulse oximetry (SpO₂ < 90%) and 100% were not detected by visual assessment.¹² Soto evaluated the efficacy of capnography in early detection of apneic events, at different flow rates of supplemental oxygen, during blinded monitored anesthesia care. Of the 39 patients, 26% developed at least 20 seconds of apnea which was undetected by the anesthesia provider. All apneic episodes were detected by capnography. Higher oxygen flow rates decreased the amplitude of the capnograph but did not interfere with apnea detection.¹³ A meta-analysis in 2011 showed respiratory depression was 17.6 times more likely to be detected during sedation cases using capnography than similar cases not monitored in the same manner. The analysis also noted that there is no support for substituting pulse oximetry for capnography and doing so can be dangerous, especially when supplemental oxygen is used.¹⁴ The administration of supplemental oxygen maintains oxygenation for a longer interval after apnea or hypoventilation has occurred. Supplemental oxygen, although vital to the patient's overall well-being, can increase the likelihood of a delay in the detection of an apneic event when the sole monitor is a pulse oximeter.³ Therefore, relying on the off-label use of pulse oximetry monitoring of the patient's ventilatory status not only decreases the margin of safety, but has been labeled as an unsafe practice by multiple investigators.^{3,12,14}

Conclusion

The utilization of capnography to monitor ventilation during procedural sedation is mandated by the ASA Standards for Basic Anesthetic Monitoring.^{3,5} The incorporation of capnography for moderate and deep sedations is certainly a logical choice to increase patient safety. This practice has evolved into a standard of monitoring during anesthesia care because it is a proven method in recognizing ventilatory events that

could potentially lead to significant morbidity and mortality.³ The benefits for the implementation of capnography during basic anesthetic monitoring include:

- Visualization of the CO₂ waveform allows for continuous assessment of the depth and frequency of each respiratory cycle.⁴
- Recognition of hypoventilation, airway obstruction and apnea enables corrective measures to be administered prior to the onset of hypoxia.³

In summary, capnography is an easy, safe and relatively inexpensive monitor which can enhance the detection of adverse respiratory events.¹⁴

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