Capnography Monitoring in Procedural Sedation for Bronchoscopy

Basem Abdelmalak, MD,* Juan Wang, MD,† and Atul Mehta, MD‡

Moderate sedation/analgesia, formerly known as “conscious sedation,” is commonly used during bronchoscopy for patients’ comfort and safety around the world. This is mostly because, during the procedure, patients may experience pain, excessive cough, and sensation of asphyxiation. These experiences may lead to anxiety, hypertension, and even arrhythmias. Moreover, they may leave behind an unpleasant memory of the procedure.¹ Moderate sedation is defined by the American Society of Anesthesiologists (ASA) as “A drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.”²

During bronchoscopy, patients may experience varying degrees of airway obstruction, due to bronchospasm, excessive cough, vocal cord edema, and bleeding, in addition to the presence of the bronchoscope in the airway. Moreover, strong cough reflex in some patients may necessitate additional doses of sedatives, compromising alertness. Collectively, these events may precipitate hypoventilation and/or apnea. Thus, in addition to the use of pulse oximetry to monitor oxygenation, the use of a ventilation monitor such as capnography during bronchoscopy might be beneficial. Pulse oximetry is thought to be an adequate monitor of ventilation. However, although it displays blood oxygenation relatively well, it actually makes monitoring ventilation challenging as it delays the detection of hypoventilation.³ Patients receiving supplemental oxygen during the procedure may not exhibit hypoxemia for a duration despite inadequate ventilation; and when detected, it might be too late to intervene and rescue. Physiologically, “hypoxemia secondary to respiratory depression occurs when an increase in alveolar CO₂ (PACO₂) produces a decrease in alveolar O₂ (PAO₂). Because pulse oximetry measures oxygen saturation (SpO₂) instead of the partial pressure of oxygen in arterial blood (PaO₂), the shape of the oxyhemoglobin dissociation curve dictates that PaO₂ will be significantly below 100 mm Hg before desaturation will be detected. Among patients breathing room air, this occurs with only modest increases in PaCO₂. However, in the presence of supplemental O₂, SpO₂ may be maintained at greater than 90% despite truly spectacular increases in arterial carbon dioxide (PaCO₂).”⁴
CHANGE IN MONITORING GUIDELINES

Conventional patient monitoring during moderate sedation includes blood pressure, pulse oximetry, and electrocardiogram. However, in October 2010, The ASA updated their statement on basic anesthesia monitoring (effective from July 2011) to include capnography in addition to clinical assessment to monitor ventilation during moderate sedation.5

This change in the statement is due to the identified risk of respiratory depression in association with all levels of sedation. “Monitored anesthesia care” (MAC), which is a term used to describe anesthesiologist’s involvement in patients’ care regardless of the level of sedation intended or achieved, mostly used to describe sedation administered by the anesthesia team, for the most part, at locations outside the operating room, is generally perceived to be much simpler and safer than the administration of general anesthesia (GA) or regional anesthesia (RA). Interestingly, according to ASA’s Closed Claims Study, this perception is unfounded.6 The study was based on 7000 claims obtained from 35 professional liability insurance companies in the United States over a period of almost 20 years. Of the 1952 claims involving surgical anesthesia, 121 (6%) were associated with MAC. Patients who had undergone procedures under MAC were older and sicker than those who had undergone GA or RA. Of note the severity of injury was similar between MAC (33% death, 8% brain damage) and those associated with GA (27% deaths, 10% brain damage). Moreover, the percentage of respiratory events was almost similar for MAC (41%) and GA (37%). Of these events, inadequate ventilation leading to inadequate oxygenation was the most common respiratory event in MAC cases.

The ASA2 and the Center for Medicare and Medicaid Services (CMS) recognized that sedation to anesthesia is a continuum and patients can slip into a deeper than intended plane of sedation without any prior warning. In fact, Patel et al7 have shown that the majority of patients undergoing moderate sedation may enter a state of deep sedation, at least for a short duration, and suggested using capnography to improve safety. This recommendation was based on their prior investigation, in which they showed that only 50% of the disordered breathing or apnea cases detected by capnography were identified with the use of pulse oximetry and none were detected by visual observation.8 Moreover, Qadeer et al9 randomized patients to either blinded or open capnography monitoring during procedural sedation, and they reported 69% versus 46% events of moderate hypoxemia and doubling of severe hypoxic events in the blinded versus open groups. They also reported increasing age as a risk factor for the hypoxemia events and concluded that capnography may improve patient safety during procedural sedation. Of note, with aging population, we are now caring for older and sicker patients undergoing bronchoscopy and related procedures using moderate sedation.

Finally, a meta-analysis has concluded that the use of capnography is associated with an 18-fold increase in detecting respiratory depression, highlighting the success of this technology in providing useful clinical information.10

PROFESSIONAL SOCIETIES AND CAPNOGRAPHY MONITORING

Other anesthesiology societies, including the Association of Anesthetists of Great Britain and Ireland (AAGBI),11 as well as the Canadian Association of Anesthetists, have adopted recommendations similar to the ASA.12 However, the response did vary among different specialty societies. The Interventional Radiology Society has issued a statement in support of the new change in the ASA document and encouraged their members to consider becoming familiar with the technology, what it has to offer, and utilizing this monitoring technology in their practices if deemed feasible.13 Also, the American Association of Maxillofacial and Oral Surgeons,14 and the American College of Emergency Physicians,15 have issued statements recommending utilization of capnography in moderate and deep sedation. In contrast, the gastroenterology societies, The American Society for Gastrointestinal Endoscopy (ASGE), The American College of Gastroenterology (ACG), and The American Gastroenterological Association (AGA), together issued a statement acknowledging the change in the ASA document but fell short of endorsing it. They claimed that there was inadequate evidence to support such a change.16 To their credit, this might be true if extreme outcomes such as mortality are taken under consideration. However, hypoxemia and apnea are also considered serious and surrogate markers of mortality by many experts17,18; avoiding them may decrease cardiac arrest and death.17 That said, a debate in ASGE News
highlighted the fact that lack of evidence is a common problem in many of the medical practices and that is where the consensus of experts plays a significant role.\(^1\) This, however, does highlight the need for randomized trials to show the impact of implementing such a strategy. However, because of the fortunate low incidence of major complications from procedural sedation, conducting such a trial in reality would require a large number of patients.\(^1\),\(^2\) It is very likely that it might end up being a case of adopting a new practice based on a consensus statement and from improvement in intermediate outcomes, as was the case with pulse oximetry when it was first introduced.\(^2\)

Another aspect of the debate over accepting capnography as a routine monitor for moderate sedation is the cost. Although it is beyond the scope of this article, briefly, there is a 1-time cost to acquire the appropriate capnography monitoring module that matches the monitoring system used in the bronchoscopy suite and to train clinicians. Moreover, per-patient cost stems from the fact that the capnography capable split cannula costs a few more dollars compared with the standard oxygen nasal cannula. Depending on the capnography unit model, there might be an additional cost for the moisture trap that may need to be replaced after each use.

**CAPNOGRAPHY**

In brief, capnography is the continuous, real-time, noninvasive measurement (numerical value) and graphical display (wave form) of the end-tidal carbon dioxide (EtCO\(_2\)).\(^2\) The principle of the capnography is based on the fact that the CO\(_2\) gas absorbs infrared waves and the amount of the waves absorbed is proportional to the concentration of the gas. The more the CO\(_2\) present, the more the infrared waves absorbed. Thus, the CO\(_2\) sensor system consists of an infrared source, sample chamber, and a detector.

Depending on the location of the CO\(_2\) sensor system, there are 2 ways to monitor CO\(_2\): mainstream and side stream. Mainstream capnography is mostly used in intubated patients. In nonintubated patients, side-stream capnography is most helpful, where a portion of gases from the nasal cannula is diverted to the analyzer located in the monitor by aspiration through a sample line (a long small bore tube) that may result in delay of CO\(_2\) measurement by a few seconds depending on its length. The cannula and the sample line, can be obliterated by vapor or secretions from the airway. The “sampling flow rate” in side-stream capnography is different from mainstream measurements. Modern capnometers utilize very low sampling flow rates (30 to 50 mL/min). Thus, use of suction during bronchoscopy does not interfere with the measurement. By the same token, the technology can also be used in infants and children with very low tidal volumes.

**CAPNOGRAPHY WAVE FORM**

During moderate sedation capnography monitoring with a split cannula, the actual CO\(_2\) value may not be accurate; however, the trend in the shape of the wave form is highly representative of the fluctuations in the degree of ventilation. Figure 1A depicts a normal capnography wave form of an EtCO\(_2\) resulting from a normal breathing pattern. Figure 1B depicts a capnography wave form of an EtCO\(_2\) demonstrating deteriorating ventilation as a result of airway obstruction developing during bronchoscopy. Figure 1C depicts a capnography wave form of an EtCO\(_2\) demonstrating the recovery of the disordered breathing pattern with patient stimulation and jaw thrust.
In conclusion, capnography is a useful monitor of ventilation. It is described by some as the “the most vital of vital signs.” It identifies respiratory depression and apnea earlier than does pulse oximetry and better than visual clinical assessment of breathing. Thus, it has been found to be helpful in decreasing the incidence of moderate and severe hypoxemia during procedural sedation. The usefulness of capnography monitoring may be more so during moderate sedation for bronchoscopy compared with other procedures. At our bronchoscopy suite, we increasingly care for older patients with advanced lung disease in addition to our high volume of post-lung transplant patients. We have adopted this technology as an additional safety measure to the current standard monitoring practice.

REFERENCES


