RESOURCE CENTER

Capnography for Nonintubated Patients: The Wave of the Future for Routine Monitoring of Procedural Sedation Patients

Debbie Sandlin, RN, CPAN

THE USE OF procedural sedation is growing dramatically because of the increase in performance of minimally invasive procedures in nonacute and acute care settings. As anesthesia agents have been refined to provide short-acting sedation with minimal side effects, procedural sedation is becoming increasingly desirable. Procedural sedation is not only commonly used in the operating room, but has many other applications such as endoscopy, radiology, cardiology, dentistry, physicians' offices, and pediatrics. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) defined 4 levels of sedation and anesthesia in January 2001.[1] These defined levels made clear that because sedation-to-anesthesia is a continuum, sedation patients should be monitored and treated the same as general anesthesia patients.

Table 1. Capnography Waveforms: Interpreting the Capnogram

A Capnogram is the graphical waveform depicting carbon dioxide (CO_2) concentration throughout respiration. End-tidal CO_2 ($EtCO_2$) refers to the measurement of carbon dioxide concentration at the end of exhalation. A normal range for $EtCO_2$ is 35–45 mmHg (4.5%–6%), similar to the range of CO_2 in arterial blood.

Key Terms:

$PaCO_2$—Partial pressure of CO_2 in arterial blood

$EtCO_2$—End-tidal carbon dioxide: measurement of the concentration of CO_2 at the end of exhalation

Capnometry—Measurement and numerical display of CO_2 concentration at the patient's airway

Capnography—Measurement and waveform display of CO_2 concentration in the patient's airway

Capnogram—Waveform display of CO_2 throughout respiration

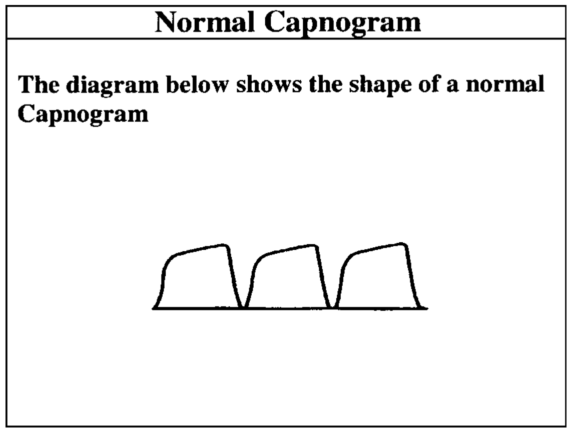

Fig 1. Normal capnogram. Reprinted with permission from Oridion Microstream Capnography Pocket Guide, page 21.

Capnography is the continuous measurement and display of carbon dioxide (CO_2) concentration in exhaled breath. A capnogram is the graphical waveform depicting CO_2 concentration throughout respiration (Table 1). A normal capnogram has a near zero baseline with a sharp rapid rise, a plateau, then a sharp rapid down shift (Fig 1). Abnormal capnograms occur for a multitude of reasons and present with varying changes from the normal (Fig 2).

Debbie Sandlin, RN, CPAN, is the Clinical Coordinator for the PACU and Presurgical Holding Unit at Southern Hills Medical Center, Nashville, TN.

Address correspondence to Debbie Sandlin, RN, CPAN, 508 Michele Dr, Antioch, TN 37013.

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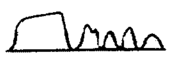
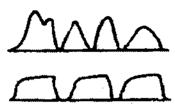
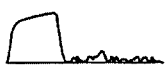
Abnormal Capnograms	
Gradually Increasing $EtCO_2$  Possible causes: • Hypoventilation • Malignant Hyperthermia • Rising body temperature • Increased metabolism • Partial airway obstruction • Absorption of CO_2 from exogenous source	**Rise in Baseline and $EtCO_2$**  Possible causes: • Defective exhalation valve • Rebreathing of previously exhaled CO_2 • Exhausted CO_2 absorber
Exponential Decrease in $EtCO_2$  Possible causes: • Cardiopulmonary arrest • Pulmonary embolism • Sudden hypotension; massive blood loss • Cardiopulmonary bypass	**Cardiogenic Oscillations**  Causes: Cardiogenic oscillations are caused by changes in thoracic volume secondary to expansion and contraction of the myocardium with each heartbeat. They are usually seen in patients with small tidal volumes and slow respiratory rates, and are of little physiologic consequence.
Sudden Decrease in $EtCO_2$ to low, non-zero value  Possible causes: • Leak in the airway system • ET tube in hypopharynx • Poorly fitting anesthetic mask • Partial airway obstruction • Partial disconnect from ventilator circuit	**Spontaneous Breathing during mechanical ventilation**  Causes: Spontaneous breathing efforts may be evident on the CO_2 waveform display. The patient on the top demonstrates poorer quality spontaneous breathing effort than the patient on the bottom.
Sudden loss of $EtCO_2$ to zero or near zero  Possible causes: • Airway disconnection • Dislodged ET tube/esophageal intubation • Totally obstructed/kinked ET tube • Complete ventilator malfunction	**Sustained low $EtCO_2$ without alveolar plateau**  Possible causes: • Incomplete exhalation • Partially kinked ET tube • Bronchospasm • Mucous plugging • Poor sampling techniques
Sustained low $EtCO_2$ with good alveolar plateau  Possible causes: • Hyperventilation • Hypothermia • Sedation, anesthesia • Dead space ventilation	**Elevated $EtCO_2$ with good alveolar plateau**  Possible causes: • Inadequate minute ventilation/hypoventilation • Respiratory-depressant drugs • Hyperthermia, pain, shivering

Fig 2. Abnormal capnograms. Reprinted with permission from Oridion Microstream Capnography Pocket Guide, pages 22–25.

Capnographs currently are used to monitor ventilator status, airway leaks, ventilator circuit disconnects, and the early onset of malignant hyperthermia in intubated ventilated patients. During procedural sedation, capnography can be used to detect hypoventilation caused by sedation or narcotics and monitor adequacy of ventilation. Current literature supports the use of capnography in the emergency room and intensive care units during procedural sedation for all ages,[2,3] and capnography is being used more frequently in pediatric dentistry[4] and in pediatric intensive care units.[5]

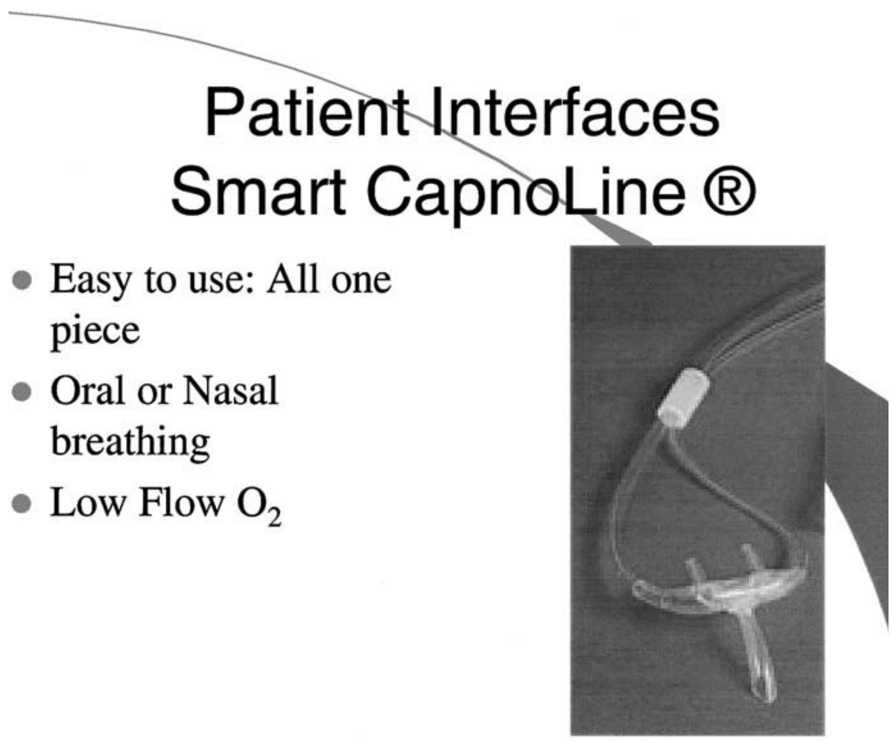


Fig 3. Oridion Smart CapnoLine divided cannula. Supplied by Oridion, with permission.

Although capnography does not eliminate the need for arterial blood gas sampling, when properly used it has the potential to reduce the frequency of some invasive procedures while still providing valuable information.[6] It certainly has implications for greater use in procedural sedation cases and may well become a standard of care in monitoring for procedural sedation.

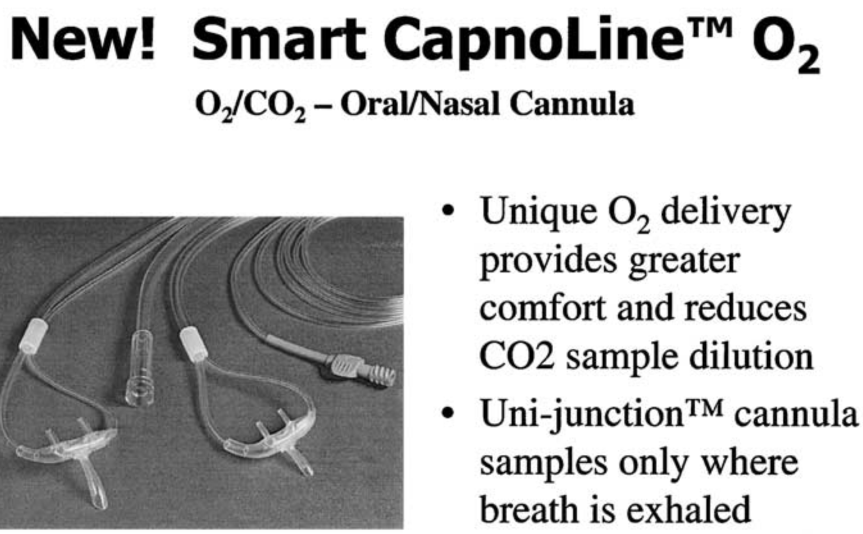


Fig 4. Oridion Smart CapnoLine CO_2 sampling solution for nonintubated patients. Supplied by Oridion, with permission.

Oridion Systems (Jerusalem, Israel) has developed the Smart Capnoline O_2, which is the first system to display an accurate waveform display of exhaled CO_2 from sedated, nonintubated patients while delivering supplemental oxygen.[7] This system displays the earliest possible warning signs of potentially fatal adverse events that may develop as a result of procedural sedation including airway obstruction, ventilatory depression, and apnea.

The Oridion Smart Capnoline uses a special cannula that is capable of measuring exhaled CO_2 from both the nose and mouth, while delivering supplemental oxygen (Fig 3). Very tiny holes are used to disperse a cloud of oxygen toward the nose and mouth while reducing CO_2 sampling dilution to a minimum (Fig 4). According to studies by Loughnan et al,[8] the divided nasal cannula more accurately reflects end tidal CO_2 partial pressure and provides a more representative waveform when compared with a traditional facemask system, while delivering adequate supplemental oxygenation. Other studies conclude that the microstream capnometer provides a more accurate end tidal CO_2 partial pressure measurement in nonintubated, spontaneously breathing patients than conventional sidestream capnometers (Fig 5).[9,10] This system provides crisp, clear waveforms and requires no routine calibration. It eliminates the problem that conventional mainstream capnometers have with excess moisture collection by using a special in-line filter.

This Oridion product is compatible with most monitoring systems, including (but not limited to) Datascope (Paramus, NJ), Datex Ohmeda (Madison, WI), Agilent Technologies-Phillips Medical Systems-Hewlett-Packard (Bathel, WA),

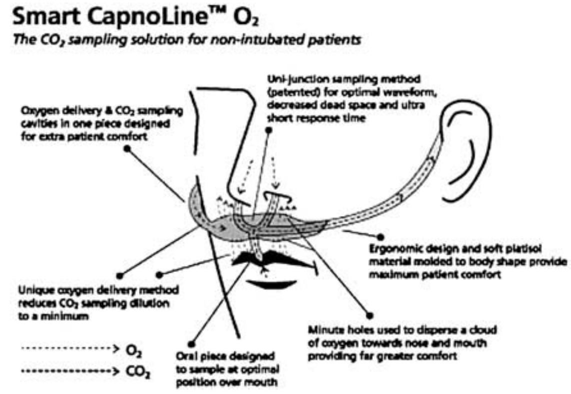


Fig 5. Interpreting the capnogram. Reprinted with permission from Oridion Microstream Capnography Pocket Guide, page 20.

Thermo Respiratory Group-Medical Data Electronics (Arleta, CA), Medtronic PhysioControl (Seattle, WA), Nellcor Puritan Bennett (Plesanton, CA), and Novametrix Medical (Wallingford, CT).

Standards for basic anesthetic monitoring developed by the American Society of Anesthesiologists (ASA) state that every patient receiving general anesthesia shall have continued monitoring for the presence of expired CO_2 unless invalidated by the nature of the patient, procedure, or equipment.[11] Now that an accurate and easy method for measurement of expired CO_2 in nonintubated, sedated patients exists, one can reasonably assume that these ASA standards may eventually be applied to procedural sedation patients to safeguard those patients who may cross the sedation-to-anesthesia continuum.

For additional information about this product, contact Oridion Medical Inc, 140 Town and Country Drive, Suite B, Danville, CA 94526, USA. 1-888-ORIDION or *www.oridion.com.*

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