CAPNOGRAPHY

Objectives:
- Review capnography concepts and common terms
- Discuss the importance of capnography during moderate sedation
- Review abnormal waveforms and readings
- Demonstrate appropriate interventions for abnormal capnography readings

History:
Used by anesthesiologists since the 1970s and has been the standard of care in the operating room since 1991
Recommendations and standards set by Joint Commission are expanding the utilization of Capnography

Definitions:
Capnometer: the numerical measurement of the carbon dioxide

![Capnometer Image]

Capnogram: the waveform display of the carbon dioxide over time

![Capnogram Image]

Capnography: a numerical value of the EtCO₂
AND
A waveform of the concentration of the CO₂ present in the airway and respiratory rate detected from actual airflow

What is Capnography?
It is a noninvasive method of measuring the exhaled carbon dioxide (EtCO₂) concentration over a period of time. The value is displayed digitally on the monitor screen. There is also a distinct waveform (tracing) for each respiratory cycle

![Capnography Image]
Detection of obstructive apnea necessitates the evaluation of oral-nasal airflow. Accurate information about the rhythm and rate of respirations can be obtained by sampling CO₂. This can be done through a nasal cannula, mask, or ventilator circuit.

**Types of CO₂ Sampling Techniques**

Colorimetric: This is a disposable detector with specially treated litmus paper that reflects color changes when qualitative amounts of CO₂ are detected. It is for intubated patients and fits on the ET tube. It is easily affected by moisture or secretions and false negatives occur during periods of poor perfusion (cardiac arrest). This device can quickly evaluate intubation success or failure.

Mainstream Capnography was also developed for the intubated patient. It has multiple disadvantages:
- Secretions block the sensor window
- Requires a sensor and cable at the airway
- Non disposable, expensive sensor replacement
- Requires routine calibration
- Difficult to use on non-intubated patients

Sidestream Capnography:
Useful for both intubated and non-intubated patients. The sensor is protected by being located inside the device. Its disadvantages are frequent tube occlusion by secretions or moisture is inaccurate in neonates, infants, and young children and also requires frequent calibration.
**Microstream Capnography** can be used with intubated or non-intubated patients and can be used in the neonatal and pediatric population. Because of low sample flow rates the lines are not flooded with moisture leading to occlusion or inaccuracy. The advanced capnography is very user friendly - it justs plugs into the monitor adaptor, requires no zeroing or calibration, uses laser technology, and is not affected by other gases.

It can be used on non-intubated patients through a nasal cannula. The small pin holes deliver oxygen around both the nose and mouth. The unijunction of sampling ports prevents dilution from non-breathing source.

It can detect the carbon dioxide levels while the patient receives supplemental oxygen and can switch between oral and/or nasal breathing. Capnography should be used for sedation and pain management but is also useful in resuscitation attempts.

**Oxygenation vs. Ventilation**

Oxygenation can be measured noninvasively through pulse oximetry (SpO₂). It detects the percentage of oxygen in the red blood cells. Any change in ventilation takes minutes to be detected. It is affected by motion artifact, poor perfusion, etc.

Ventilation is measured by end-tidal CO₂ and detects the partial pressure (mmHg) or volume (% vol) of CO₂ in the airway at the end of exhalation. The breath to breath measurement provides information within seconds and is not affected by motion artifact or poor perfusion. The respiratory cycle has two separate physiologic processes; oxygenation and ventilation.

The comparison between capnography and pulse oximetry is:

**Capnography**
- Carbon Dioxide
- Reflects ventilation
- Hypoventilation/apnea detected immediately
- Reflects ventilation changes within 10 seconds
- Should be used with pulse oximetry

**Pulse Oximetry**
- Oxygen saturation
- Reflects oxygenation
- SpO₂ changes lag when patient is hypoventilating or apneic
- Reflects change in oxygenation with 5 minutes
- Should be used with capnography
**Capnography Capabilities**

The gold standard to determine successful intubation is capnography. Also because capnography directly correlates with cardiac output, it's beneficial in the cardiac arrest patient to help determine the effectiveness of CPR compressions, recognize the return of spontaneous circulation and assist with decisions regarding the termination of resuscitation.

Capnography has also been demonstrated to be beneficial in non-intubated patients by providing EtCO₂ readings and displaying the related waveforms. The waveform configuration can be used in intubated and non-intubated patients to assess ventilation adequacy, metabolic status, and circulation effectiveness. The normal capnogram will consist of box-like waveforms directly related to the different phases of the respiratory cycle.

![Normal Capnography Waveform](image)

There is an inverse correlation between EtCO₂ and the respiratory rate.

↓ RR = ↑ CO₂ → hypoventilation

↑ RR = ↓ CO₂ → hyperventilation

**Wave Forms**

Patients who are hyperventilating will have a capnogram with a faster respiratory rate but lower waveform amplitude resulting from the decreased CO₂ in each breath.
Patients who are hypoventilating will have a lower respiratory rate but higher amplitude of waveforms, resulting from the increased amount of CO₂ in each breath.

The last basic capnographic waveform results from the physiological effects of bronchospasm. Bronchospasm causes a slower and more erratic emptying of CO₂ from the alveoli, which results in a slower rise in the expiratory upstroke. Instead of the normal box-like waveform, the presence of bronchospasm results in the characteristic shark-fin shape of the bronchospastic waveform.
Respiratory Uses
Sedated patients or those receiving pain management can be monitored for hypoventilation and capnography can assist in decision regarding the continued use of sedatives or pain medications. During sedation, monitoring of the ventilatory status is imperative and the focus is on the baseline EtCO$_2$ prior to sedation as well as the respiratory rate.

Capnography can also guide the need for intubation or assisted intubation for the overdose patient.

Capnography can also guide the patient with hyperventilation and anxiety symptoms. Hyperventilations with normal or high EtCO$_2$ levels are more likely to have pathology involvement whereas hyperventilation with low EtCO$_2$ levels is more likely to reflect anxiety. Patients and families can even be empowered to use the waveforms as a biofeedback technique to decrease the respiratory rate.

Metabolic Emergencies
Capnography can also be beneficial in evaluating diabetic ketoacidosis and to differentiate diabetic ketoacidosis and hyperglycemic hyperosmolar non-ketotic coma.

Hypothermia and hyperthermia severity can be determined by capnography and the clinical decisions be altered. Metabolic acidosis associated with gastroenteritis can have severity determined with capnography.

Interpretation of Capnography Results
An elevated level indicates carbon dioxide retention because of a decreased respiratory drive and/or hypoventilation. It may indicate hyperventilation or respiratory depression with low tidal volumes. Most research describes the following criteria as significant findings requiring intervention:

- Absolute change in EtCO$_2$ of 10 mm Hg or greater
- EtCO$_2$ 50 mm Hg or greater
- Absent waveform = apnea
**Interventions:** least invasive to most invasive

1. Reposition the patient's head to restore airway patency
2. Verbal or physical stimulation to encourage the patient to breathe
3. Decrease medication doses
4. Stopping medications
5. Administration of reversal agents
6. Bag mask ventilation

The completion of the procedure does not end the risk of respiratory depression. Some studies found the highest EtCO2 levels occurred after the end of the procedure but before the patients returned to their baseline level of consciousness.

**Supplemental Oxygen**

Supplemental oxygen may delay the onset of hypoxia which may delay the recognition of hypoventilation. Knowing this, EtCO2 monitoring is more likely to be helpful if supplemental oxygen is used during sedation.

**Need for Capnography**

Capnography can detect early phases of respiratory depression which can allow more precise and safe use of medications. Despite routine use of pulse oximetry in Endoscopy over the past 20 years, the incidence of cardiopulmonary complications hasn't decline yet in contrast anesthesia-related deaths have dropped since the use of capnography with general anesthesia in the United States. "Monitoring of exhaled carbon dioxide should be considered for all patients receiving deep sedation and for patients whose ventilation cannot be directly observed during moderate sedation." (Practice Guidelines for Sedation and Analgesia by Non-anesthesiologists, 2002).
Capnography Benefits:
- Accurately monitors respiratory rate
- Monitors adequate ventilation with non-intubated patients
- Early indicator of airway obstruction
- Early warning of apnea
- Monitors potential risk of over-sedation resulting in hypoventilation more effectively than pulse oximetry.
- Adds an additional level of patient safety

References:
Emergency Nurses Association (2009.) Emergency nursing resource: The use of capnography during procedural sedation/analgesia in the emergency department