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- Rapid assessment and triage tool
- Monitoring obstructive lung disease
- Monitoring hypoventilation states
- Monitoring diabetes

Microstream® Technology

Case studies
Basic Definitions in Capnography
Objectives

This module will review:
- Capnography terminology and definitions
- Differences between oxygenation and ventilation
- Physiological functions addressed by capnography
- The physiology behind the EtCO₂ waveform
**Terminology**

- **Capnos** – in Greek means “smoke” from the breath
- **Capnometer** – numerical measurement only
- **Capnograph** – number + waveform
What is Capnography and Who is it For?

Non-invasive, continuous measurement of carbon dioxide in the breath

- **Capnography can be used on:**
  - Intubated patients, via an airway adapter
  - Spontaneously breathing patients, via an oral/nasal FilterLine® CO₂ sampling line
    - Switch breathing is defined as alternating oral and nasal breathing
What is Capnography?

Capnography provides:
- Numerical value for end tidal CO₂ (EtCO₂)
- CO₂ waveform for each breath
- Respiratory rate (RR) sampled directly from the airway

EtCO₂ value + Waveform + RR = Airway status
Limited Number of Methods for Monitoring Respiratory Rate (RR)

- Observation or auscultation by the clinician
  - Accuracy may be limited by patient movement or positioning
  - No automated documentation or alarm
Limited Number of Methods for Monitoring Respiratory Rate (RR)

- Impedance monitoring - recording chest wall or abdominal movement with ECG leads
  - Accuracy may be affected by repositioning, postural changes, or diaphoresis
  - Unreliable during obstructive apnea
Capnography Accurately Measures Respiratory Rate (RR)

- Capnography provides the most accurate method of measuring respiratory rate (RR)
  - Digitally records RR in real time, with each breath
  - Calculates RR directly at the mouth and/or nose
  - Allows clinician to recognize obstructive apnea
Oxygenation and Ventilation

The respiratory cycle consists of 2 separate physiological processes:

**Oxygenation** = pulse oximetry
Process of getting oxygen to the tissues

**Ventilation** = capnography
Process of eliminating CO₂ from the body
When Breathing Stops: SpO$_2$ vs. EtCO$_2$
The Journey of A Molecule Through the Respiratory Cycle
Capnography Assesses Physiological Functions

- METABOLISM
- PERFUSION
- VENTILATION

ALL THREE ARE IMPORTANT!

CO₂ produced by cellular metabolism → CO₂ carried by blood to lungs → Diffusion out of blood
Understanding the Normal Waveform

- A-B: Anatomical dead space - no CO$_2$ in breath
- B-C: Rapid rise in CO$_2$ – middle part of exhalation
- C-D: Alveolar plateau – CO$_2$ at steady state; alveolar emptying
- D: End exhalation or end of the tidal breath (EtCO$_2$)
- D-E: Inhalation

The normal range for EtCO$_2$ is 35 to 45 mmHg (7.5 mmHg=1 volume % or 1kPa)
**Benefits of Capnography**

- Continuous monitoring device, as useful as ECG

- Instantaneous feedback on patient’s clinical status

- Objective confirmation of clinical assessment allows for easy assessment of response to treatment

- The earliest indicator of adverse airway and respiratory events

- Allows you to intervene before serious complications develop
Capnography for the Intubated Patient in Pre-hospital Care
Applications in the Intubated Patient

- Verification of initial endotracheal tube (ETT) placement
- Continuous monitoring of ETT position
- Monitoring cardiac output during cardiac arrest and CPR
- CO₂ titration in patients with suspected increased cranial pressure
Verifying ETT Placement

Clinical signs can be unreliable:

- Fogging of the tube
- Detection of breath sounds over the stomach and chest
- Observation of chest wall movement

Capnography is the most reliable means of confirmation
Carbonated beverages or Antacids affect EtCO$_2$ readings

- **Intubation**
  - Carbonated beverages or antacids can show a false positive reading for presence of CO$_2$
  - After 4-6 positive pressure breaths, abdominal CO$_2$ is eliminated

- Therefore – after intubation true EtCO$_2$ reading comes after the sixth breath
“Standard physical examination methods, such as auscultation of lungs and epigastrium, visualization of chest movement, and fogging in the tube, are not sufficiently reliable to exclude esophageal intubation in all situations.”

“Verification of Endotracheal Tube Placement” Approved by the ACEP Board of Directors.” October 2001. Policy #400307. 
http://www.acep.org/webportal/Templates/Default_Primary_Print.aspx?NRNODEGUID={B6107D0B-4DEB-479B-81F2-02BE6FEB2244}
Reduce Patient Risk with Continuous Monitoring

Capnography

- Immediately detects ETT dislodgement
  - immediate change in waveform
- Identifies the location of the dislodged tube in some instances
Check Waveform Changes for Location of ETT Dislodgement

ETT dislodgement in esophagus

ETT Tube dislodgement in hypopharynx
Documentation is Critical

- Use capnography to document tube position throughout transport
- Print out waveform strips at critical intervals
  - At time of initial intubation
  - After repositioning tube if dislodgement occurs
  - On arrival at the hospital
Value of Capnography in Low Perfusion States, Cardiac Arrest and ICP Patients

- Monitoring perfusion in shock & low perfusion state conditions
- Measures effectiveness of cardiac compressions in cardiac arrest
- Earliest indicator of Return of Spontaneous Circulation (ROSC)
- Able to closely titrate CO$_2$ levels in ICP patients
Identify Shock and Low Perfusion States

“Measurement of PetCO$_2$ is a non-invasive alternative for continuous assessment of cardiac output during low flow circulatory shock states of diverse causes.”

EtCO₂ Can Assess Chest Compression Effectiveness

- Use EtCO₂ to assess the depth, rate, and force of chest compressions
CPR: Assess Chest Compressions

Increase in EtCO$_2$ has been shown to correlate with
- A fresh rescuer at a faster compression rate
- A new rescuer during CPR with no change in rate
- Mechanical compressions

Better compressions lead to higher EtCO$_2$ levels and improved perfusion

Capnography Detects Return of Spontaneous Circulation

**Indications of ROSC**
- Sudden, sustained rise in EtCO$_2$ from baseline
  - This can occur before a pulse or blood pressure are palpable
- **Pulse detection may be delayed**
  - Arterial vasoconstriction may make pulse difficult to initially detect
CPR: Detect ROSC

- 90 pre-hospital patients intubated in the field
- 16 survivors
- In 13 survivors a rapid rise in measured exhaled CO₂ was the earliest indicator of ROSC
  - before a pulse or blood pressure were palpable

Using Capnography for Predictive Outcomes

Capnography

- Has been shown to predict the probability of outcome following resuscitation

- May be used in the decision to cease resuscitation efforts

Value of Capnography for Patients with Increased Intracranial Pressure

- When CO$_2$ levels are low, less blood to brain
- When CO$_2$ levels are high, more blood to brain

Types of patients with suspected increased intracranial pressure (ICP)

- Head trauma
- Brain tumors
- Brain abscesses (HIV patients)
- Brain infections (meningitis, encephalitis)
- Spontaneous bleeds (arteriovenous malformations, aneurysms)
Titration of CO₂ Levels in the ICP Patient

- Important **not** to hypoventilate (EtCO₂ > 45mmHg) these patients as this will further increase intracranial pressure.

- **Capnography can be used to precisely titrate CO₂ levels**
Capnography for the Non-intubated Patient in Pre-hospital Care
Objectives

Capnography for the non-intubated patient will be reviewed in the following contexts

• As a rapid assessment and triage tool
• For monitoring obstructive lung disease
• For monitoring hypoventilation states
• For monitoring diabetes
Rapid Assessment and Triage Tool

Critically ill patients

- Accurate and reliable
- No motion artifact
- ABCs in <15 seconds
Rapid Assessment and Triage Tool

- **Capnography provides:**
  - Waveform as a graphic representation of breathing
  - Waveform indicates if airway is patent
  - Normal EtCO$_2$ value indicates adequate perfusion
Rapid Assessment and Triage Tool

- No motion artifact
- Reliable in low perfusion states
  - Therefore: Accurate and reliable in actively seizing patients
Capnography in Seizing Patients

- **Seizing patient who is not breathing**
  - No waveform, no respiratory effort
- **Ineffectively ventilating seizing patient**
  - Low height of waveform, low EtCO$_2$
- **Effectively ventilating seizing patient**
  - Normal waveform, normal EtCO$_2$
Rapid Assessment for Critically Ill Patients

Common conditions detected by capnography:

- Not breathing
- Upper airway obstruction
- Laryngospasm
- Bronchospasm
- Respiratory failure
No breath

- No waveform
- No breath at airway
- No EtCO$_2$ reading
Upper Airway Obstruction / Laryngospasm

Upper airway obstruction
- No waveform
- Chest wall movement
- No breath sounds
- Responsive to airway alignment maneuvers

Waveform returns

Laryngospasm
- No waveform
- Chest wall movement
- No breath sounds
- Unresponsive to airway alignment maneuvers

Waveform remains flat line
Upper Airway Obstruction vs/ Laryngospasm

“Capnography can provide rapid identification and assessment of the common complications of chemical agents including: apnea, upper airway obstruction, laryngospasm … Response to airway alignment maneuvers (chin lift, jaw thrust) can further distinguish upper airway obstruction from laryngospasm.”

Bronchospasm or Airway Obstruction (e.g. Foreign Body)

- Characteristic change in waveform shape
Respiratory Failure and the Relationship to Differences Between Oxygenation and Ventilation

Oxygenation desaturation: physical indicators
- Cyanosis

Changes in status of ventilation
- Changes in ventilatory pattern

Measured by Pulse Oximetry
Measured by Capnography

Capnography provides a complete picture of patient’s ventilatory status
Capnography in Obstructive Lung Disease

- Waveform shape detects presence of bronchospasm
- EtCO$_2$ trends assess disease severity (e.g., asthma, emphysema)
- EtCO$_2$ trends gauges response to treatment (e.g., asthma, emphysema)
Capnography in Asthma

- Capnography during asthma attack provides important objective information
- Stable asthma patients: normal waveforms and normal EtCO₂
Capnography in Asthma

- **Patients with a mild asthma attack**
  - Low EtCO$_2$ due to hyperventilation
Capnography in Asthma

- **Patients with a moderate asthma attack**
  - Begin to tire
  - Decreased respiratory rate
  - Increased EtCO₂ rising to normal
Capnography in Asthma

- Patients with a severe asthma attack
  - Hypoventilation

Capnography during severe asthma attack provides objective, important information to help effectively manage the patient.
Continuous EtCO₂ Trending Assesses Ventilatory Status

- Assess response to treatment
- Continually monitor patient’s status using EtCO₂ trends
EtCO$_2$ Trending in COPD
Capnography in Obstructive Lung Disease

- Clinical assessment of COPD patient is primarily subjective

- Capnography provides information supporting the clinician's judgment that is:
  - Accurate
  - Reliable
  - Objective
Capnography’s Role in Determination of the Degree of Hypoventilation and Possible Respiratory Failure

“Valuable information about ventilatory status can be gleaned from the capnogram. ... A rising phase III with no plateau is seen with prolonged exhalation and in lower airway obstruction such as seen in asthma.”

Capnography in COPD: Evaluation of various waveform shape indicators

Relationship Between PaCO₂ and EtCO₂

- Patients with normal lung function
  - Arterial-alveolar gradient = 2-5 mmHg
  - EtCO₂ ~ PaCO₂
  - Use EtCO₂ spot checks

- Patients with ventilation/perfusion mismatch
  - Increased gradient
  - EtCO₂ ≠ PaCO₂
  - Use EtCO₂ trends
Hypoventilation States

- Sedation and analgesia
- Alcohol intoxication or drug ingestion
- Post-ictal states
Sedation and Analgesia

- Medications can affect ventilatory status

**Analgesia**
- Fentanyl
- Morphine
- Meperidine

**Sedation**
- Diazepam
- Lorazepam
- Midazolam

**EtCO₂ trends**
- Determine degree of hypoventilation
- Early indicator of respiratory failure
Respiratory Patterns

Normal

Hypoventilation
Patients with Alcohol Intoxication or Drug Ingestion

Excessive alcohol alone or combined with sedative drugs can cause
- Severe hypoventilation
- Obtundation
- Respiratory failure

Capnography provides the earliest indicator of impending respiratory failure
Capnography in Post-ictal Patients

- Monitor ventilatory status with EtCO$_2$ trends and waveform

- **Effective ventilation**
  Normal waveform, normal EtCO$_2$ trends

- **Ineffective ventilation**
  Low waveform, low EtCO$_2$ trends

- **Respiratory failure**
  No waveform, no chest wall movement, no spontaneous airflow
Capnography Assesses Physiological Functions

- METABOLISM
- PERFUSION
- VENTILATION
Capnography and Diabetic Ketoacidosis (DKA)

- As the patient becomes more acidotic, the respiratory rate increases and the EtCO$_2$ decreases.
Case example #1: 19-year old in DKA

- $\text{EtCO}_2 = 11$
- RR = 22
- pH 7.01
Case example #2: 17-year old in DKA

- EtCO₂=6
- pH 6.93
“End-tidal CO\textsubscript{2} is linearly related to HCO\textsubscript{3} and is significantly lower in children with DKA. If confirmed by larger trials, cut-points of 29 torr and 36 torr, in conjunction with clinical assessment, may help discriminate between patients with and without DKA, respectively”.

Capnography provides

- Real-time measurement of ventilatory status
- Dynamic monitoring
- Advanced warning of adverse events
- Opportunity to avoid the progression of an adverse event
- Objective confirmation of clinical assessment
Thank you