CAPNOGRAPHY
In Emergency Care

EDUCATIONAL SERIES

Part 2:
Introduction
Part 2: Introduction to Capnography
Part 2: Introduction to Capnography
Learning Objectives

- Differentiate between oxygenation and ventilation
- Define end-tidal CO$_2$
- Identify phases of a normal capnogram
- Recognize patterns of hypoventilation, hyperventilation and bronchospasm
Oxygenation and Ventilation

What is the difference?
Oxygenation and Ventilation

• **Two completely different and separate functions**
  - Oxygenation is the transport of O₂ via the bloodstream to the cells
    • Oxygen is required for metabolism
  - Ventilation is the exhaling of CO₂ via the respiratory tract
    • Carbon dioxide is a byproduct of metabolism
Oxygenation and Ventilation

Ventilation (capnography)

Oxygenation (oximetry)

Cellular Metabolism
Oxygenation

• Measured by pulse oximetry (SpO₂)
  – Noninvasive measurement
  – Percentage of oxygen in red blood cells
  – Changes in ventilation take minutes to be detected
  – Affected by motion artifact, poor perfusion and some dysrhythmias
Oxygenation

Pulse Oximetry Sensors

Pulse Oximetry Waveform
Ventilation

• Measured by the end-tidal CO$_2$
  – Partial pressure (mmHg) or volume (% vol) of CO$_2$ in the airway at the end of exhalation
  – Breath-to-breath measurement provides information within seconds
  – Not affected by motion artifact, poor perfusion or dysrhythmias
Ventilation

Capnography Lines

Capnography waveform
Oxygenation versus Ventilation

- Monitor your own SpO$_2$ and EtCO$_2$
- SpO$_2$ waveform is in the second channel
- EtCO$_2$ waveform is in the third channel
Oxygenation versus Ventilation

- Now hold your breath
- Note what happens to the two waveforms

How long did it take the EtCO$_2$ waveform to go flat line?

How long did it take the SpO$_2$ to drop below 90%?
Oxygenation and Ventilation

**Oxygenation**
- Oxygen for metabolism
- $\text{SpO}_2$ measures % of $O_2$ in RBC
- Reflects change in oxygenation within 5 minutes

**Ventilation**
- Carbon dioxide from metabolism
- $\text{EtCO}_2$ measures exhaled CO$_2$ at point of exit
- Reflects change in ventilation within 10 seconds
Why Measure Ventilation—Intubated Patients

- Verify and document ET tube placement
- Immediately detect changes in ET tube position
- Assess effectiveness of chest compressions
- Earliest indication of ROSC
- Indicator of probability of successful resuscitation
- Optimally adjust manual ventilations in patients sensitive to changes in CO$_2$
Why Measure Ventilation—Non-Intubated Patients

- Objectively assess acute respiratory disorders
  - Asthma
  - COPD
- Possibly gauge response to treatment
Why Measure Ventilation—Non-intubated Patients

• Gauge severity of hypoventilation states
  – Drug and ETOH intoxication
  – Congestive heart failure
  – Sedation and analgesia
  – Stroke
  – Head injury

• Assess perfusion status

• Noninvasive monitoring of patients in DKA
Interpreting $\text{EtCO}_2$ and the Capnography Waveform

- Interpreting $\text{EtCO}_2$
  - Measuring
  - Physiology
- Capnography waveform
End-tidal CO₂ (EtCO₂)

Pulmonary Blood Flow

Perfusion

Ventilation

Right Ventricle

Artery → Oxygen → Vein

CO₂ → O₂

Left Atrium
End-tidal CO₂ (EtCO₂)

• **Carbon dioxide can be measured**

• **Arterial blood gas is PaCO₂**
  - Normal range: 35-45mmHg

• **Mixed venous blood gas PeCO₂**
  - Normal range: 46-48mmHg

• **Exhaled carbon dioxide is EtCO₂**
  - Normal range: 35-45mmHg
a-A Gradient

Arterial to Alveolar Difference for CO$_2$

Ventilation

Perfusion

Right Ventricle → Artery → Alveolus → Vein → Left Atrium

PaCO$_2$  EtCO$_2$
End-tidal CO$_2$ (EtCO$_2$)

• **Normal a-A gradient**
  – 2-5mmHg difference between the EtCO$_2$ and PaCO$_2$ in a patient with healthy lungs
  – Wider differences found
    • In abnormal perfusion and ventilation
    • Incomplete alveolar emptying
    • Poor sampling
End-tidal CO$_2$ (EtCO$_2$)

- Reflects changes in
  - *Ventilation* - movement of air in and out of the lungs
  - *Diffusion* - exchange of gases between the air-filled alveoli and the pulmonary circulation
  - *Perfusion* - circulation of blood
End-tidal CO₂ (EtCO₂)

- Monitors changes in
  - **Ventilation** - asthma, COPD, airway edema, foreign body, stroke
  - **Diffusion** - pulmonary edema, alveolar damage, CO poisoning, smoke inhalation
  - **Perfusion** - shock, pulmonary embolus, cardiac arrest, severe dysrhythmias
Capnographic Waveform

• Normal waveform of one respiratory cycle
• Similar to ECG
  – Height shows amount of CO₂
  – Length depicts time
Capnographic Waveform

- Waveforms on screen and printout may differ in duration
  - On-screen capnography waveform is condensed to provide adequate information in 4-second view
  - Printouts are in real-time
  - Observe RR on device
Capnographic Waveform

- Capnograph detects only CO$_2$ from ventilation
- No CO$_2$ present during inspiration
  - Baseline is normally zero
Capnogram Phase I

*Dead Space Ventilation*

- Beginning of exhalation
- No CO₂ present
- Air from trachea, posterior pharynx, mouth and nose
  - No gas exchange occurs there
  - Called “dead space”
Capnogram Phase I

Baseline

Beginning of exhalation
Capnogram Phase II

Ascending Phase

- \( \text{CO}_2 \) from the alveoli begins to reach the upper airway and mix with the dead space air
  - Causes a rapid rise in the amount of \( \text{CO}_2 \)

- \( \text{CO}_2 \) now present and detected in exhaled air
Capnogram Phase II

Ascending Phase

CO₂ present and increasing in exhaled air
Capnogram Phase III
Alveolar Plateau

- CO$_2$ rich alveolar gas now constitutes the majority of the exhaled air
- Uniform concentration of CO$_2$ from alveoli to nose/mouth
Capnogram Phase III
Alveolar Plateau

Alveolar Plateau

CO₂ exhalation wave plateaus
Capnogram Phase III

End-Tidal

• End of exhalation contains the highest concentration of CO$_2$
  – The “end-tidal CO$_2$”
  – The number seen on your monitor

• Normal EtCO$_2$ is 35-45mmHg
Capnogram Phase III
*End-Tidal*

End of the wave of exhalation
Capnogram Phase IV

Descending Phase

- Inhalation begins
- Oxygen fills airway
- CO$_2$ level quickly drops to zero
Capnogram Phase IV
Descending Phase

Descending Phase Inhalation

Inspiratory downstroke returns to baseline
Capnography Waveform

Normal Waveform

Normal range is 35-45mm Hg (5% vol)
Capnography Waveform Question

- How would your capnogram change if you intentionally started to breathe at a rate of 30?
  - Frequency
  - Duration
  - Height
  - Shape
Hyperventilation

RR ↑: EtCO₂ ↓

Normal

Hyperventilation
Capnography Waveform Question

• How would your capnogram change if you intentionally decreased your respiratory rate to 8?
  – Frequency
  – Duration
  – Height
  – Shape
Hypoventilation

RR ↓: EtCO₂ ↑

Normal

Hypoventilation
Capnography Waveform Question

How would the waveform shape change during an asthma attack?
Bronchospasm Waveform Pattern

- Bronchospasm hampers ventilation
  - Alveoli unevenly filled on inspiration
  - Empty asynchronously during expiration
  - Asynchronous air flow on exhalation dilutes exhaled CO$_2$

- Alters the ascending phase and plateau
  - Slower rise in CO$_2$ concentration
  - Characteristic pattern for bronchospasm
  - “Shark Fin” shape to waveform
Part 2:  
Introduction to Capnography Summary

• Oxygenation and ventilation

• Pulse oximetry
  – Measures $O_2$ saturation in blood
  – Slow to indicate change in ventilation

• Capnography
  – Measures $CO_2$ in the the airway
  – Provides a breath-to-breath status of ventilation
Part 2:
Introduction to Capnography Summary

• Capnographic waveform has four phases
• The highest CO₂ concentration is at the end of alveolar plateau
  – End-tidal CO₂
  – Normal EtCO₂ range is 35-45mmHg
• Several conditions can be immediately detected with capnography
Capnography Waveform Patterns

- Normal
- Hyperventilation
- Hypoventilation
- Bronchospasm
Part 2: Introduction to Capnography

We’re off to a running start!