It’s Time to Start Using it!

Capnography 101
Oxygenation and Ventilation

What is the difference?
Oxygenation and Ventilation

Oxygenation (oximetry)

Ventilation (capnography)

O2

CO2

Cellular Metabolism
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 CO$_2$ present
- Air from trachea, posterior pharynx, mouth and nose
  - No gas exchange occurs there
  - Called “dead space”
Capnogram Phase I

Beginning of exhalation

Baseline
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

Ascending Phase
Early Exhalation

CO$_2$ 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
- $\text{CO}_2$ 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 \downarrow : EtCO_2 \uparrow

Normal

Hypoventilation
Capnography Waveform Patterns

- Normal
- Hyperventilation
- Hypoventilation
Capnography Waveform Question

How would the waveform shape change during an asthma attack?
Capnography Waveform Patterns

Normal

Bronchospasm
Capnography Waveform Patterns

- Normal
- Hyperventilation
- Hypoventilation
- Bronchospasm
End-tidal CO₂ (EtCO₂)

• Carbon dioxide can be measured
• Arterial blood gas is PaCO₂
  – Normal range: 35-45mmHg
• Exhaled carbon dioxide is EtCO₂
  – Normal range: 35-45mmHg
End-tidal CO₂ (EtCO₂)

- 2-5mmHg difference between the EtCO₂ and PaCO₂ in a patient with healthy lungs
- Wider differences found
  - In abnormal perfusion and ventilation
  - Incomplete alveolar emptying
  - Poor sampling
The Intubated Patient
Confirm ET Tube Placement

• Traditional methods of confirmation
  – Listen for breath sounds
  – Observe chest movement
  – Auscultate stomach
  – Note ET tube clouding

These methods are subjective and unreliable
Confirm ET Tube Placement

“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.”

Source: Verification of Endotracheal Tube Placement - Approved by the ACEP Board of Directors, October 2001 http://www.acep.org/1,4923,0.html (policy statement)
Confirm ET Tube Placement
Confirm ET Tube Placement

- ET tube placement in esophagus may briefly detect CO₂
  - Following carbonated beverage ingestion
  - When gastric distention was produced by mouth to mouth ventilation
- Residual CO₂ will be washed out after 6 positive pressure breaths
Detect ET Tube Displacement

- A properly placed ET tube can be displaced out of the trachea without any movement of the proximal tip

Detect ET Tube Displacement

• Traditional methods of monitoring tube position
  – Periodic auscultation of breath sounds
  – Gastric distention
  – Worsening of patient’s color
• Late sign of tube displacement

These methods are subjective and unreliable—and delayed
Detect ET Tube Displacement

- **Capnography**
  - Immediately detects ET tube displacement

Confirm ET Tube Placement

• Capnography provides
  – Documentation of correct placement
  – Ongoing documentation over time
  – Documentation of correct position at ED arrival
Capnography in Cardiopulmonary Resuscitation

- Assess chest compressions
- Early detection of ROSC
- Objective data for decision to cease resuscitation
CPR: Assess Chest Compressions

• Under conditions of constant ventilation, capnography correlates with the circulatory status produced by chest compressions

• EtCO$_2$ has potential value in monitoring effectiveness of CPR

CPR: Assess Chest Compressions

• Rescuer fatigue
• Ochoa Study
  – Rescuers were not able to maintain adequate chest compressions for more than 1 minute
  – Rescuers did not perceive fatigue even when it was measurably present

CPR: Detect ROSC

- Sudden rise in EtCO$_2$
- Confirm with ECG and capnography
- Questionable pulse
  - Arterial vasoconstriction may make pulse difficult to detect
CPR: Detect ROSC

• Briefly stop CPR and check for organized rhythm on ECG monitor
Decision to Cease Resuscitation

• Capnography
  – Has been shown to predict probability of outcome following resuscitation
  – May be used in the decision to cease resuscitation efforts

Decision to Cease Resuscitation

- 120 prehospital patients in nontraumatic cardiac arrest
- EtCO₂ had 90% sensitivity in predicting ROSC
- Maximal level of <10mmHg during the first 20 minutes after intubation was never associated with ROSC

Decision to Cease Resuscitation

- Capnography provides another objective data point in making a difficult decision.
Optimize Ventilation

- Monitor ventilation efforts and carbon dioxide levels with capnography
- Carbon dioxide has a profound affect on cerebral blood flow (CBF)
  - Influences intracranial pressure (ICP)
Optimize Ventilation

• Use capnography to titrate EtCO₂ levels in patients sensitive to fluctuations

• Patients with suspected increased intracranial pressure (ICP)
  – Head trauma
  – Stroke
  – Brain tumors
  – Brain infections
The Non-intubated Patient

CC: “trouble breathing”
The Non-intubated Patient
CC: “trouble breathing”
Capnography in Bronchospastic Conditions

- Air trapped due to irregularities in airways
- Uneven emptying of alveolar gas
  - Dilutes exhaled CO$_2$
  - Slower rise in CO$_2$ concentration during exhalation
Capnography in Bronchospastic Diseases

- Changes ascending phase (II) with loss of the sharp upslope
- Alters alveolar plateau (III) producing a “shark fin”
Capnogram of Asthma

Changes seen with increasing bronchospasm

COPD Case Scenario

• 72 year old male
• C/O difficulty breathing
• History of CAD, CHF, smoking and COPD
• Productive cough, recent respiratory infection
• Pulse 90, BP 158/82  RR 27
Capnography in Bronchospastic Conditions

COPD Case Scenario

Initial Capnogram A

Initial Capnogram B
Capnography in Hypoventilation States

• Altered mental status
  – Sedation
  – Alcohol intoxication/Drug Ingestion
  – Stroke/CNS infections/Head injury

• Abnormal breathing

• CO₂ retention
  – EtCO₂ >50mmHg
Capnography in Hypoventilation States

- $\text{EtCO}_2$ is above 50mmHg
- Box-like waveform shape is unchanged

Time condensed; actual rate is slower
Capnography in Hypoventilation States

Case Scenario

• Observer called 911
• 76 year old male sleeping and unresponsive on sidewalk, “gash on his head”
• Known history of hypertension, EtOH intoxication
• Pulse 100, BP 188/82, RR 10, SpO₂ 96% on room air
Capnography in Hypoventilation States

Hypoventilation

Time condensed; actual rate is slower
Capnography in Low Perfusion

- Capnography reflects changes in Perfusion
  - Pulmonary blood flow
  - Systemic perfusion
  - Cardiac output
Capnography in Low Perfusion

Case Scenario

Low EtCO₂ seen in low cardiac output

Ventilation controlled