Capnography 101

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Expected Outcomes

1. Gain a working knowledge of the physiology and science behind End-Tidal CO₂.
2. Relate End-Tidal CO₂ to ventilation, perfusion, and metabolism.
3. Review the clinical efficacy and pitfalls of using End-Tidal CO₂ to drive patient care.
The best thing an old firefighter can teach a young firefighter is how to be an old firefighter!

DFitch
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Current Practice Survey
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
<table>
<thead>
<tr>
<th>POX Capers</th>
<th>Nail polish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor peripheral perfusion</td>
<td>Acrylic nails **</td>
</tr>
<tr>
<td>Hypotension</td>
<td>Increasingly inaccurate with BP</td>
</tr>
<tr>
<td>Hypo-perfusion</td>
<td>below 80 systolic</td>
</tr>
<tr>
<td>Vasoconstriction</td>
<td>(hypo-perfusion)</td>
</tr>
<tr>
<td></td>
<td>Probe location</td>
</tr>
</tbody>
</table>

**Trauma Patients?**
<table>
<thead>
<tr>
<th>Oxygen Saturation</th>
<th>PaO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>90 mmHg</td>
</tr>
<tr>
<td>90%</td>
<td>60 mmHg</td>
</tr>
<tr>
<td>60%</td>
<td>30 mmHg</td>
</tr>
<tr>
<td>50%</td>
<td>27 mmHg</td>
</tr>
</tbody>
</table>
Probe location choice

maybe as long as 30 sec lag time if probe is out in the customary position, ie distal finger/toe.

Forehead or earlobe are closer to central circulation, giving quicker information in critically ill patients (SHOCK / TRAUMA)
Pulse Ox Limitations

PaO₂ of 80 – 400 mmHg correlates with SPO₂ within normal range*

No measure of cardiac performance

1. Your decreased cardiac output patients who experience rapid desaturation and have delayed response to pulmonary ventilation should not surprise you.

Normal PaO₂ does NOT ensure adequate ventilation!

1. Minimal volume of gas exchange is often acceptable for oxygenation. **CO₂ removal relies on adequate pulmonary ventilation.**
Can We Do Better?
Oximetry and Capnography

Pulse oximetry measures oxygenation

Capnography measures ventilation and provides a graphical waveform available for interpretation
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
THIS IS WHY
YOU NEVER TAKE THE TOP BAG
ETCO$_2$

Directly measures – Elimination of CO$_2$

Indirectly measures:

1. Changes in tissue level production of CO$_2$
2. Delivery to lungs via circulation
CO₂ Elimination
Metabolic production
Venous return
Pulmonary circulation

Monitoring way more than just a number!
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 CO$_2$ (EtCO$_2$)

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
Oxygenation and Ventilation

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

**Ventilation**
- Carbon dioxide from metabolism
- $\text{EtCO}_2$ measures exhaled $\text{CO}_2$ at point of exit
- Reflects change in ventilation within 10 seconds
ETCO₂ / PaCO₂ Correlation

ETCO₂ is usually 2-5 mmHg less than PaCO₂.

In healthy patients...
Capnography Waveform Patterns

- **Normal**
- **Hyperventilation**
- **Hypoventilation**
Basic Capnogram

- Measured EtCO₂
- Alveolar plateau
- Inspiratory downstroke
- Expiratory upstroke
- Respiratory baseline (should be 0 mmHg)
Capnography Waveform Patterns

- **Normal**
- **Hyperventilation**
- **Hypoventilation**
Waveform:
Regular Shape, Plateau Below Normal

Indicates CO$_2$ deficiency
✓ Hyperventilation
✓ Decreased pulmonary perfusion
✓ Hypothermia
✓ Decreased metabolism

Interventions
✓ Adjust ventilation rate
✓ Evaluate for adequate sedation
✓ Evaluate anxiety
✓ Conserve body heat
Hyperventilation

RR: EtCO₂

Normal

Hyperventilation
When would a rapid RR not show decreased ETCO₂?
Waveform: Regular Shape, Plateau Above Normal

Indicates increase in ETCO$_2$

✓ Hypoventilation
✓ Respiratory depressant drugs
✓ Increased metabolism

Interventions

✓ Adjust ventilation rate
✓ Decrease respiratory depressant drug dosages
✓ Maintain normal body temperature
Hypoventilation

RR ↓ : EtCO₂ ↑

![Graph showing normal and hypoventilation conditions with RR and EtCO₂ levels.](image-url)
When would a slow RR not show an elevated ETCO₂?

Hypothermia / Pre-arrest Hypo-metabolic states
Bronchospasm Waveform Pattern

Bronchospasm hampers ventilation
• Alveoli unevenly filled on inspiration
• Empty asynchronously during expiration
• Asynchronous air flow on exhalation dilutes exhaled $\text{CO}_2$

Alters the ascending phase and plateau
• Slower rise in $\text{CO}_2$ concentration
• Characteristic pattern for bronchospasm
• “Shark Fin” shape to waveform
Capnography Waveform Patterns

Normal

Bronchospasm
Capnography in Bronchospastic Conditions

Capnogram of Asthma

Changes in $d\text{CO}_2/dt$ seen with increasing bronchospasm

Capnography in Bronchospastic Conditions

COPD Case Scenario

Initial Capnogram A

Initial Capnogram B
Capnography Waveform Patterns

- **Normal**
- **Hyperventilation**
- **Hypoventilation**
- **Bronchospasm**
Ok Wizards...
Muscle Relaxants (curare cleft)

- Appear when muscle relaxants begin to subside
- Depth of cleft is inversely proportional to degree of drug activity
Now what?
An abrupt increase in PETCO₂ may indicate return of spontaneous circulation (ROSC). Increase in pulmonary circulation brings more CO₂ into lungs for elimination.
CAPNOGRAM

Sudden loss of waveform
- ET tube disconnected, dislodged, kinked or obstructed
- Loss of circulatory function

Decreasing EtCO₂
- ET tube cuff leak
- ET tube in hypopharynx
- Partial obstruction

CPR Assessment
- Attempt to maintain minimum of 10mmHg

Sudden increase in EtCO₂
- Return of spontaneous circulation (ROSC)

Bronchospasm (“Shark-fin” appearance)
- Asthma
- COPD

Hypoventilation

Hyperventilation

Decreased EtCO₂
- Apnea
- Sedation

www.dnbpediatrics.com
Context
Mechanism: Cardiac Output

Preload
Afterload
Rate
Rhythm
Contractility
Cardiac Output and ETCO$_2$

Low CO via hypovolemia - does not carry enough CO$_2$ per minute for exchange and exhalation.

Decreased ETCO$_2$

How do we interpret low ETCO$_2$? – hyperventilation? Poor lung function?

Decreased perfusion to the lungs ALONE can cause this finding!
Mechanism: ETCO$_2$ and Shock

CO$_2$ to lungs decreased

Alveolar PACO$_2$ decreases

Increase in alveolar dead space – decreased ETCO$_2$

Lower perfusion dilutes CO$_2$ available to alveoli
ETCO$_2$ and sustained Shock

CO$_2$ accumulates in distal tissues and venous blood

Return back to lungs in greater concentration

Increasing ETCO$_2$

Compensation mechanisms further help to maintain acceptable ETCO$_2$
Can ETCO₂ be used to predict / dx Shock?

Recent evidence of ETCO₂ being a predictor of high lactate levels
SHOCK leads to decreased ETCO₂ and Increased Lactate -
SHOCK INDEX

HR / Systolic BP

Normal between 0.5 and 0.8

120/80 with HR  80     80/120
= 0.67
Current uses for ETCO\textsubscript{2}

ETT placement confirmation

Cardiac arrest
  1. indicator of impending ROSC
  2. Indicator of unlikely survival.

Critical patient transport monitoring – another VS

Trauma???
Capnography and RSI

When considering sedation – the MOST sensitive indicator of hypoventilation and apnea is ETCO\textsubscript{2}!

1. Many studies have indicated a high rate of acute respiratory events, such as hypoventilation and apnea.

CHEST RISE assessment is not sensitive for detecting these events*
ETCO₂ and Respiratory Distress

With few exceptions, most patients who are in significant respiratory distress are hypercapnic.

What may be one of the exceptions?
Optimize Ventilation

Use capnography to titrate EtCO$_2$ levels in patients sensitive to fluctuations

Patients with suspected increased intracranial pressure (ICP)

• Head trauma
• Stroke
• Brain tumors
• Brain infections
The Future of ETCO$_2$

**DKA in Pediatric patients**
1. Relationship to HCO$_3$ and ETCO$_2$ (lower ETCO$_2$ can confirm DKA)

**PE**
1. Decreasing ETCO$_2$ in the face of hyperventilation (increase alveolar dead space)

**Field Disaster Triage**
1. What does it measure? (perfusion, ventilation, metabolism)

**Anxiety control**
1. Patients focus on the monitor and making the numbers change, causing general improvement in their condition.

**Respiratory Rate analysis**
1. Studies show health care professionals do a poor job of grabbing an accurate respiratory rate.
ETCO₂ is a valuable, multi-faceted tool

ETCO₂ is helpful in monitoring ventilation, perfusion, and metabolism

ETCO₂ can be helpful in hypoperfusion caused by trauma / shock and the TBI herniating patient

More research and correlation between ETCO₂ and trauma / Shock is necessary to drive trauma care

Research is ongoing as to additional uses for ETCO₂ technology
Thank you...
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