CAPNOGRAPHY -
The New Standard of Care
CAPNOGRAPHY

Why use it?
Capnography & Pulse Oximetry

- **CO₂:**
  - Reflects ventilation
  - Detects apnea and hypoventilation immediately
  - Should be used with pulse oximetry

- **O₂ Saturation:**
  - Reflects oxygenation
  - 30 to 60 second lag in detecting apnea or hypoventilation
  - Should be used with capnography
Indications for Use - End-Tidal CO₂ Monitoring

- Validation of proper endotracheal tube placement
- Detection and Monitoring of Respiratory depression
- Hypoventilation
- Obstructive sleep apnea
- Procedural sedation
- Adjustment of parameter settings in mechanically ventilated patients
ETCO₂ & Cardiac Resuscitation

- **Non-survivors**
  
  Average ETCO₂: 4-10 mmHg

- **Survivors (to discharge)**
  
  Average ETCO₂: >30 mmHg
ETCO$_2$ & Cardiac Resuscitation

- If patient is intubated and pulmonary ventilation is consistent with bagging, ETCO$_2$ will directly reflect cardiac output.
- Flat waveform can establish PEA.
  - Increasing ETCO$_2$ can alert to return of spontaneous circulation.
- Configuration of waveform will change with obstruction.
Capnography

What are we measuring?
Respiration—The BIG Picture

1. Cellular Metabolism of food into energy: $O_2$ consumption and $CO_2$ Production

2. Transport of $O_2$ and $CO_2$ between cells and pulmonary capillaries, & diffusion from/into alveoli.

3. Ventilation between alveoli & atmosphere
Capnography Depicts Respiration

Metabolism → Transport → Ventilation

CO₂ → CO₂ → CO₂

ETCO₂
34
RR
15
Physiological Factors Affecting ETCO₂ Levels

Increase in ETCO₂
- Increased muscular activity (shivering)
- Malignant hyperthermia
- Increased cardiac output (during resuscitation)
- Bicarbonate infusion
- Tourniquet release
- Effective drug therapy for bronchospasm
- Decreased minute ventilation

Decrease in ETCO₂
- Decreased muscular activity (muscle relaxants)
- Hypothermia
- Decreased cardiac output (cardiac arrest)
- Pulmonary embolism
- Bronchospasm
- Increased minute ventilation
Normal Arterial & ETCO$_2$ Values

Arterial CO$_2$ (PaCO$_2$)
Arterial Blood Gas Sample (ABG)

- Normal PaCO$_2$ Values
  - 35 - 45 mmHg
  - 4.7 - 6.0 kPa
  - 4.6 - 5.9%

ETCO$_2$
from Capnograph

- Normal ETCO$_2$ Values
  - 30 - 43 mmHg
  - 4.0 - 5.7 kPa
  - 4.0 - 5.6%
Deadspace

- Ventilated areas which do not participate in gas exchange

Total Deadspace = Anatomic + Alveolar + Mechanical

- **Anatomic Deadspace**: airways leading to the alveoli
- **Alveolar Deadspace**: ventilated areas in the lungs without blood flow
- **Mechanical Deadspace**: artificial airways including ventilator circuits
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Theory of Operation
Infrared Absorption

- A beam of infrared light energy is passed through a gas sample containing CO$_2$
- CO$_2$ molecules absorb specific wavelengths of infrared light energy.
- Light emerging from sample is analyzed.
- A ratio of the CO$_2$ affected wavelengths to the non-affected wavelengths is reported as ETCO$_2$
Capnography vs. Capnometry

**Capnography:**
- Measurement and display of both ETCO₂ value and capnogram (CO₂ waveform)
- Measured by a capnograph

**Capnometry:**
- Measurement and display of ETCO₂ value (no waveform)
- Measured by a capnometer
Mainstream vs. Sidestream
Quantitative vs. Qualitative ETCO$_2$

- **Quantitative ETCO$_2$:**
  - Provides an actual numeric value
  - Found in capnographs and capnometers

- **Qualitative ETCO$_2$:**
  - Only provides a range of values
  - Termed “CO$_2$ Detectors”
Colorimetric CO$_2$ Detectors

- A “detector” – not a monitor
- Uses chemically treated paper that changes color when exposed to CO$_2$
- Must match color to a range of values
- Requires six breaths before determination can be made
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The Capnogram
Elements of a Waveform

Dead Space

Beginning of exhalation

Alveolar Gas

Alveolar gas mixes with dead space

End of exhalation

Inspiration
The Capnogram:
- Provides validation of the ETCO$_2$ value
- Visual assessment of patient airway integrity
- Verification of proper ETT placement
- Assessment of ventilator/breathing circuit integrity
The Normal $\text{CO}_2$ Waveform

A – B  Baseline
B – C  Expiratory Upstroke
C – D  Expiratory Plateau
D     ETCO$_2$ value
D – E  Inspiration begins
- A normal capnogram is the best evidence that the ETT is correctly positioned.
- With an esophageal tube little or no CO$_2$ is present.
Inadequate Seal Around ETT

- Possible causes:
  - Leaky or deflated endotracheal or tracheostomy cuff
  - Artificial airway too small for the patient
Hypoventilation (increase in ETCO$_2$)

- Possible causes:
  - Decrease in respiratory rate
  - Decrease in tidal volume
  - Increase in metabolic rate
  - Rapid rise in body temperature (hypothermia)
Hyperventilation (decrease in ETCO₂)

- Possible causes:
  - Increase in respiratory rate
  - Increase in tidal volume
  - Decrease in metabolic rate
  - Fall in body temperature (hyperthermia)
Rebreathing

Possible causes:
- Faulty expiratory valve
- Inadequate inspiratory flow
- Insufficient expiratory flow
- Malfunction of CO₂ absorber system
Obstruction

Possible causes:

- Partially kinked or occluded artificial airway
- Presence of foreign body in the airway
- Obstruction in expiratory limb of the breathing circuit
- Bronchospasm
Muscle Relaxants

“Curare Cleft”:
- Appears when muscle relaxants begin to subside
- Depth of cleft is inversely proportional to degree of drug activity
Faulty Ventilator Circuit Valve

- Baseline elevated
- Abnormal descending limb of capnogram
- Allows patient to rebreathe exhaled gas
Sudden Loss of Waveform

- Apnea
- Airway Obstruction
- Dislodged airway (esophageal)
- Airway disconnection
- Ventilator malfunction
- Cardiac Arrest
Waveform:
Regular Shape, Plateau Below Normal

• Indicates CO₂ deficiency
  ✓ Hyperventilation
  ✓ Decreased pulmonary perfusion
  ✓ Hypothermia
  ✓ Decreased metabolism

• Interventions
  ✓ Adjust ventilation rate
  ✓ Evaluate for adequate sedation
  ✓ Evaluate anxiety
  ✓ Conserve body heat
Waveform: Regular Shape, Plateau Above Normal

- Indicates increase in ETCO$_2$
  - Hypoventilation
  - Respiratory depressant drugs
  - Increased metabolism
  - Fever, pain, shivering

- Interventions
  - Adjust ventilation rate
  - Decrease respiratory depressant drug dosages
  - Assess pain management
  - Conserve body heat