Capnography

McHenry Western Lake County
EMS
What is Capnography?

- Capnography is an objective measurement of exhaled CO2 levels.
- Capnography measures ventilation.
- It can be used to:
  - Assist in confirmation of intubation.
  - Continually monitor the ET tube placement during transport.
  - Assess ventilation status.
  - Assist in assessment of perfusion.
  - Assess the effectiveness of CPR.
  - Predict critical patient outcomes.
Term capnography comes from the Greek work *KAPNOS*, meaning smoke.

Anesthesia context: inspired and expired gases sampled at the Y connector, mask or nasal cannula.

Gives insight into alterations in ventilation, cardiac output, distribution of pulmonary blood flow and metabolic activity.
Capnography
- Measurement and display of both ETCO$_2$ value and capnogram (CO$_2$ waveform)
- Measured by a capnograph

Capnometry
- Measurement and display of ETCO$_2$ value (no waveform)
- Measured by a capnometer
Pulmonary Physiology

- Oxygenation vs Ventilation
- Metabolic Respiration
- The EMS version!
Oxygenation – How we get oxygen to the tissues

Ventilation (the movement of air) – How we get rid of carbon dioxide.
Cellular Respiration

Glucose (sugar) + Oxygen → Carbon dioxide + Water + Energy (as ATP)
Alveolar Respiration
Capnography vs Pulse Oximetry

- Capnography provides an immediate picture of patient condition. Pulse oximetry is delayed. Hold your breath.
- Capnography will show immediate apnea, while pulse oximetry will show a high saturation for several minutes.
Capnography vs Pulse Oximetry

Good pulse...good Spo2....No Capnography!
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 airway
  - Provides a breath-to-breath status of ventilation
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

- CO₂ from the alveoli begins to reach the upper airway and mix with the dead space air
  - Causes a rapid rise in the amount of CO₂
- CO₂ now present and detected in exhaled air
Capnogram Phase II
Ascending Phase

CO₂ present and increasing in exhaled air

Ascending Phase
Early Exhalation
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
End of exhalation contains the highest concentration of CO₂
- The “end-tidal CO₂”
- The number seen on your monitor

Normal EtCO₂ is 35-45mmHg
- Normal is relative NOT absolute
Capnogram Phase III

End-Tidal

End of the wave of exhalation
Capnogram Phase IV

**Descending Phase**

- Inhalation begins
- Oxygen fills airway
- CO₂ level quickly drops to zero

![diagram](image.png)
Capnogram Phase IV

Descending Phase

Inspiratory downstroke returns to baseline
Capnography Waveform

Normal Waveform

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

Note: This is Relative NOT absolute
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 Patterns

- Normal
- Hyperventilation
- Hypoventilation
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
2 Techniques for Monitoring ETCO2

- 2 methods for obtaining gas sample of analysis
  - Mainstream
  - Sidestream

- Mainstream (Flow-through or In-line)
  - Adapter placed in the breathing circuit
  - No gas is removed from the airway
  - Adds bulk to the breathing system
  - Electronics are vulnerable to mechanical damage
Mainstream Analyzer
Sidestream Analyzer

- Sidestream (aspiration)
  - Aspirate gas from an airway sampling site and transport the gas sample through a tube to a remote CO2 analyzer
  - Provides ability to analyze multiple gases
  - Can use in non-intubated patients
  - Potential for disconnect or leak giving false readings
  - Withdrawals 50 to 500ml/min of gas from breathing circuit (most common is 150-200ml/min)
  - Water vapor from circuit condenses on its way to monitor
    - A water trap is usually interposed between the sample line and analyzer to protect optical equipment
Sidestream Analyzer
Medtronics Analyzers
Zoll Capnostat Sensor
Displays
Displays
Displays
Displays
Colorimetric 
Etco2 
Sensor
Colorimetric Etco2 Sensor

Remember!!

“Good as Gold”
“Yellow is Sunshine”
“Yellow is YES!!”

“Purple is Poop”
Location of Sensor

- The location of CO$_2$ sensor greatly affects the measurement.

- Measurement made further from the alveolus can become mixed with fresh gas, causing a dilution of CO$_2$ values and rounding of capnogram.
How ETCO₂ Works

- ETCO₂ monitoring determines the CO₂ concentration of exhaled gas
- Photo detector measures the amount of infrared light absorbed by airway gas during inspiration and expiration
  - CO₂ molecules absorb specific wavelengths of infrared light energy
  - Light absorption increases directly with CO₂ concentration
- A monitor converts this data to a CO₂ value and a corresponding waveform (capnogram)
Capnography

- Expressed in numerical value in mm Hg.
- Normal value between of 35 – 45 mm Hg.
- For all age groups.
Capnography

- If the number is > 45, the CO2 is high.
  - Hypoventilation
  - Respiratory Acidosis
- If the number is < 35, the CO2 is low.
  - Hyperventilation
  - Respiratory Alkalosis.
Interpreting Capnography

- Capnography (Numerical)
- Capnogram (Visual)
- ROSC

“A 2005 study comparing field intubations that used continuous capnography to confirm intubations vs. non-use showed zero unrecognized misplaced intubations in the monitoring group vs. 23% misplaced tubes in the unmonitored group.”

- Annals of Emergency Medicine, May 2005
Confirm ET Tube Placement

Capnography provides
- Objective confirmation of correct tube placement
- Documentation of correct placement
Confirm ET Tube Placement
Confirm ET Tube Placement

- ET tube placement in esophagus may briefly detect CO$_2$
  - Following carbonated beverage ingestion
  - When gastric distention was produced by mouth to mouth ventilation

- Residual CO$_2$ will be washed out after 6 positive pressure breaths
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
The Capnogram

- Provides validation of ETCO$_2$ value
- Visual assessment of patient airway integrity
- Verification of proper ET tube placement
- Assessment of ventilator / breathing circuit integrity
Possible Causes:
- Missed intubation
- A normal capnogram is the best evidence that the ET tube is correctly positioned
- With ET tube in the esophagus, little or no CO₂ is present
Inadequate Seal Around ET Tube

Possible Causes:

- Leaky or deflated endotracheal or tracheostomy cuff
- Artificial airway is too small for the patient
  - Connections on sample tubing loose
Increasing ETCO₂

- Hypoventilation (decrease RR or TV)
- Increase in metabolic rate
- Increase in body temperature
- Sudden increase in blood pressure
Decreasing ETCO₂

- **Gradual**
  - Hyperventilation (increase RR or TV)
  - Decrease in metabolic rate
  - Decrease in body temperature

- **Rapid**
  - Embolism (air or thrombus)
  - Sudden hypotension
  - Circulatory arrest
Increase in Inspired CO2
(Rise in Baseline)

- CO2 absorbent exhausted
- Faulty expiratory valve
- Calibration error in monitor
- Water in analyzer
Loss of Plateau / Sloping of ETCO2 Waveform

- Obstruction of expiration (asthma, COPD, bronchospasm)
- No plateau is reached prior to next inspiration
- Kinked endotracheal tube
Patient is inspiring during exhalation phase of mechanical ventilation

PaCO2 increasing cause spontaneous respiration

Increasing pain
Cardiogenic Oscillations

- Caused by beating of heart against lungs
Decision to Cease Resuscitation

Capnography provides another objective data point in making a difficult decision.
The Non-intubated Patient
CC: “trouble breathing”

Asthma?
Emphysema?
Bronchitis?
Pneumonia?
Cardiac ischemia?
CHF?
PE?
The Non-intubated Patient
CC: “trouble breathing”

- Identifying the problem and underlying pathogenesis
- Assessing the patient’s status
- Anticipating sudden changes
The Non-intubated Patient Capnography Applications

- Identify and monitor bronchospasm
  - Asthma
  - COPD

- Assess and monitor
  - Hypoventilation states
  - Hyperventilation
  - Low-perfusion states
The Non-intubated Patient
Capnography Applications

Capnography reflects changes in

- **Ventilation** - movement of gases in and out of the lungs
- **Diffusion** - exchange of gases between the air-filled alveoli and the pulmonary circulation
- **Perfusion** - circulation of blood through the arterial and venous systems
The Non-intubated Patient
Capnography Applications

Ventilation

- Airway obstruction
  - Smooth muscle contraction
  - Bronchospasm
  - Airway narrowing
  - Uneven emptying of alveoli
  - Mucous plugs
The Non-intubated Patient Capnography Applications

**Diffusion**
- Airway inflammation
- Retained secretions
- Fibrosis
- Decreased compliance of alveoli walls
- Chronic airway modeling (COPD)
- Reversible airway disease (Asthma)
Capnography in Bronchospastic Conditions

- Air trapped due to irregularities in airways
- Uneven emptying of alveolar gas
  - Dilutes exhaled CO₂
  - Slower rise in CO₂ concentration during exhalation
Capnography in Bronchospastic Diseases

- Uneven emptying of alveolar gas alters emptying on exhalation
- Produces changes in ascending phase (II) with loss of the sharp upslope
- Alters alveolar plateau (III) producing a “shark fin”
Capnography in Bronchospastic Conditions

Capnogram of Asthma

Changes in CO₂ seen with increasing bronchospasm

Capnography in Bronchospastic Conditions

Asthma Case Scenario

- 16 year old female
- C/O “having difficulty breathing”
- Visible distress
- History of asthma, physical exertion, “a cold”
- Patient has used her “puffer” 8 times over the last two hours
- Pulse 126, BP 148/86, RR 34
- Wheezing noted on expiration
Capnography in Bronchospastic Conditions

Asthma Case Scenario

Initial

After therapy
Capnography in Bronchospastic Conditions

Pathology of COPD

- Progressive
- Partially reversible
- Airways obstructed
  - Hyperplasia of mucous glands and smooth muscle
  - Excess mucous production
  - Some hyper-responsiveness

Hyperplasia: An abnormal increase in the number of cells in an organ or a tissue with consequent enlargement.
Capnography in Bronchospastic Conditions

Pathology of COPD

- Small airways
  - Main sites of airway obstruction
  - Inflammation
  - Fibrosis and narrowing
  - Chronic damage to alveoli
  - Hyper-expansion due to air trapping
  - Impaired gas exchange
Capnography in Bronchospastic Conditions

Capnography in COPD

- Arterial CO₂ in COPD
  - PaCO₂ increases as disease progresses
  - Requires frequent arterial punctures for ABGs

- Correlating capnograph to patient status
  - Ascending phase and plateau are altered by uneven emptying of gases

- PaC02 is the (P)artial pressure of (a)rterial (C02) in the human body. In other words, it is a calculation of the amount of carbon dioxide present in the artery of a person. The normal level is 35-45 mmHg. An amount greater than 45 is dangerous, even life-threatening.
Capnography in Bronchospastic Conditions

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
Case Scenario

- 88 year old male
- C/O: Short of breath
- H/O: MI X 2, on oxygen at 2 L/m
- Pulse 66, BP 114/76/p, RR 36 labored and shallow, skin cool and diaphoretic, 2+ pedal edema
- Initial SpO₂ 69%; EtCO₂ 17mmHG
Capnography in CHF

Case Scenario

- Placed on non-rebreather mask with 100% oxygen at 15 L/m; IV Fentanyl and SL Nitroglycerin as per local protocol
- Ten minutes after treatment:
  - SpO₂ 69% → 99%
  - EtCO₂ 17 mmHg → 35 mmHg

Time condensed to show changes
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

- EtCO₂ 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 Hypoventilation States

Hypoventilation in shallow breathing
Capnography in Low Perfusion

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

Case Scenario

- 57 year old male
- Motor vehicle crash with injury to chest
- History of atrial fib, anticoagulant
- Unresponsive
- Pulse 100 irregular, BP 88/p
- Intubated on scene
Capnography in Low Perfusion

Case Scenario

Low EtCO$_2$ seen in low cardiac output

Ventilation controlled
Capnography in Pulmonary Embolus

Case Scenario

- 72 year old female
- CC: Sharp chest pain, short of breath
- History: Legs swollen and pain in right calf following flight from Alaska
- Pulse 108 and regular, RR 22, BP 158/88 SpO$_2$ 95%
Capnography in Pulmonary Embolus

Case Scenario

Strong radial pulse

Low EtCO$_2$ seen in decreased alveolar perfusion
Capnography in Seizing Patients

Only accurate and reliable modality for assessment of ventilatory status

Helps to distinguish between

- Central apnea
- Ineffective ventilations
- Effective ventilations
Capnography in DKA

The more acidotic the patient, the lower the HCO3 and the higher the respiratory rate and lower the EtCO2.

Helps is distinguishing DKA vs HHNK.
Capnography use with a Head Injured Patient

- Helps to avoid hyperventilation
- Target value of 35mmHg is recommended
The Non-intubated Patient Summary

- Identify and monitor bronchospasm
  - Asthma
  - COPD

- Assess and monitor
  - Hypoventilation states
  - Hyperventilation
  - Low perfusion
  - Many others now being reported
Capnography will detect a tracheal intubation, every time.
MYTH!

- Don’t forget your time tested assessments.
- Will not detect a right main stem intubation.

Carbonated Beverages!
I saw the tube go through the cords, and my capnometer reads zero. I must have missed.
MYTH!

- NEVER forget your time tested assessments!
- What if the body is not making CO2?
  - Cellular Death
  - Extreme Hypothermia
  - Extended down time without CPR
Capnography Fact or Myth?

Capnography is just another confusing thing I don’t need to know about and doesn’t need to be on the ambulance!
MYTH!

- Airway Management poses the 2nd highest risk of liability for EMS.
  - What is the riskiest?
- It's easy to use!
  - Just look for the little boxes!
- Much better indicator than pulse oximetry.
  - Pulse oximetry is oxygenation….ETC02 is ventilation!
Review

The normal value of ETCO2 and for what ages?
Review

35 – 45 mm HG for all ages
Review

The clear plastic piece is disposable or reusable?
Review

DISPOSABLE!
Can capnography be used on the King Tube?
Review

YES!

- **Latex Free and Single Patient Use**
- **Orientation / X-ray Line**
- **Single Valve / Pilot Balloon**
  - Inflates both the proximal and distal cuffs.
- **Two Ventilation Outlets**
  - In front of the larynx for efficient ventilation and allows passage of fiberoptic bronchoscope or tube exchange catheter.
- **CM Depth Markings**
- **Proximal Cuff**
  - Stabilizes KING LT-D and seals the oropharynx.
- **Bilateral Eyelets**
  - Additional eyelets to supplement ventilation.
- **Distal Cuff**
  - Blocks entry of esophagus. Reduces the possibility of gastric insufflation.
How long can Capnography be used?
Review

Capnography is used as long as EMS feels it provides benefit for the patient.
Review

Does Capnography hurt?
Review

The device is harmless and causes no pain or discomfort to the patient.
Case Study

You have one of your fellow crew members ventilating a cardiac arrest victim.

Capnography has been applied after the tube (ET or King) has been inserted and an EtCo2 of 19 has been found.

What should you do next?
Case Study

- Your crew would want to slow the respiratory rate to bring the EtCo2 up to a normal level of 35 – 45.
- Continue to monitor the patients Spo2 and EtCo2 readings during transport.
Question?

You have one of your crew ventilating a Traumatic Head Injury patient and the initial EtCo2 reading that you obtain is 49. This reading indicates that you will need to:

- A) Slow the respiratory rate
- B) Increase the respiratory rate
- C) Does not matter what this is. We need 100% on the Sp02
- D) Increase the flow of 02 into the BVM
You have one of your crew ventilating a Traumatic Head Injury patient and the initial EtCo2 reading that you obtain is 49. This reading indicates that you will need to:

- **A)** Slow the respiratory rate
- **B)** Increase the respiratory rate
- **C)** Does not matter what this is. We need 100% on the Sp02
- **D)** Increase the flow of O2 into the BVM
Case Study

You are treating a full arrest and have hooked up your capnography to your advanced airway. You have a reading of 0 and no waveform. Is this reason to remove your airway?
What should you do....
Case Study

- Listen to lung sounds
- Look for symmetrical chest rise
- Vapor in the tube
- Change in patient color
- Absent abdominal sounds
- Re-visualize placement of tube
- EIDD
6 year old has overdosed on parents pain medications. Agonal respirations of 7 were noted on your arrival. You have inserted an appropriate sized King Tube and you see the following wave form.
Leaking or inadequate inflation of airway cuff
Is this color good or bad?
Purple is Poop!
Sources

- Capnography for Paramedics. http://emscapnography.blogspot.com
- Medtronic ERS
Special Thanks

Staci Rivas, CRNA, MSN
KU Nurse Anesthesia Department
Jeff Lesniak, EMT-P
Woodstock Fire Rescue District
&
Medtronics Corporation
for the use of their materials in this presentation
Now let’s play!!

Everyone needs to see how their specific departments EtCo2 monitor works