MICROSTREAM® CAPNOGRAPHY: The use and benefits in intubated and nonintubated patients

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LT/PM SCFD 7
Course Overview

- Capnography Overview
- Physiology
- Oxygenation vs. Ventilation
- History of Capnography
Course Overview

- Technology Advances
- Understanding the Waveform
- Capnography uses in EMS
  - Intubated uses
  - Non-intubated uses
Capnography Overview

Why use capnography?

Why should I learn capnography?
End Tidal CO₂ - What is It?

- Breathing is done in waves
- EtCO₂ is the amount of CO₂ measured at the peak of the wave
- EtCO₂ is measured at nose, mouth, or hub of the ET tube
Capnography Overview

- A technology that
  - Provides another measurement in assessing your patient
  - Gives an objective measure of your patient’s ventilatory status
  - Shows a graphic picture of your patient’s ventilatory status
  - Presents an early warning of changes in your patient's cardiopulmonary status
  - Supplies important documentation on your patient
PHYSIOLOGY
Physiology of CO$_2$

ALL THREE ARE IMPORTANT!

METABOLISM  PERfusion  VENTILATION
Physiology of Carbon Dioxide Production

**Oxygen** -> lungs -> alveoli -> blood

- **Oxygen**
- **CO₂**
- **lungs**
- **breath**
- **blood**

**CO₂**

**Production**

- **Oxygen**
- **cells**
- **energy**

**Glucose**

**Oxygen**

**muscles + organs**
The Relationship Between PaCO$_2$ and EtCO$_2$

- EtCO$_2$ normal range is 35 - 45 mmHg
- Under normal ventilation and perfusion conditions, the PaCO$_2$ & EtCO$_2$ will be very close
  - 2 - 5 mmHg with normal physiology
- Wider differences found in abnormal perfusion and ventilation
Oxygenation and Ventilation

What is the difference?
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
Oxygen Desaturation Curve
Trend Summary Desaturation
Oxygenation and Ventilation

- **Oxygenation**
  - Oxygen for metabolism
  - $\text{SpO}_2$ measures % of $O_2$ in RBC
  - Reflects change in oxygenation within 5 minutes
  - Sensitive to artifact, motion, poor perfusion

- **Ventilation**
  - Carbon dioxide from metabolism
  - $\text{EtCO}_2$ measures exhaled $CO_2$ at point of exit
  - Reflects change in ventilation within 10 seconds
  - Accurate with motion and poor perfusion
History of Capnography in EMS

- Used by anesthesiologists since the 1970s
- Standard of care in the OR since 1991
- New standards and technologies now expanding utilization

Conventional Technologies

- Mainstream

- Sidestream
History of Capnography in EMS

Capnography Technologies

- Conventional high-flow sidestream
- Mainstream
- Microstream® technology
History of Capnography in EMS

Conventional high-flow sidestream capnography system

150-200 cc/min flow rate

Sample Port

Air Sample

Bag

Water Trap

End-tidal CO₂ monitor with sensor inside
Conventional Sidestream Technologies

**Advantages**
- No sensor at airway
- Intubated & non-intubated applications

**Disadvantages**
- Requires routine zero & calibration
- Requires high sample flow rate (150-250 ml/min)
- Secretions block sampling tube
- Requires external filter & water trap
- Competes for tidal volume in infants & neonates
History of Capnography

- Mainstream Capnography
Mainstream Conventional Technology

**Advantages**
- Sensor on airway / real time

**Disadvantages**
- Requires routine zero & calibration
- Requires sensor & cable at airway
- Heavy sensor on the airway
- Expensive sensor replacement
- Secretions block sensor window
- Only intubated patient populations
- Not able to use on non-intubated patients
**Microstream® Technology**

- **Microstream® technology improves upon conventional sidestream technology**

  - Focused CO₂ specific IR beam
    - Not affected by any other gases
  - Low sample flow rate
    - 50 ml/min
  - Miniature sample cell
    - 15 microliters
Microstream® Technology

Microstream® technology improves upon conventional sidestream technology

Advantages

- No sensor at airway
- No routine calibration
- Automatic zeroing
- Neonatal through adult
- Intubated and non-intubated patients
- Promotes superior moisture handling
- Accurate at small tidal volumes and high respiratory rates (pediatrics/neonates)
**Microstream® Capnography**

- A combination of a unique CO\(_2\) sidestream measurement technology and FilterLine\textsuperscript{®} sampling line for improved breath sampling.

- Only system providing accurate EtCO\(_2\) readings for non-intubated patients receiving supplemental O\(_2\) and switch between oral and/or nasal breathing.
Microstream® Capnography
Major Benefits

- Ease of use
- Reliable technology
- Flexibility; applicable for all patient types
- Versatile for all care environments
- Latest in capnography technological advancements
**Microstream® Capnography Advantages**

**Ease of Use**
- No expensive sensors to replace
- Yearly calibration – done in 5 minutes by BioMed
- Quick warm up time ~40 seconds from **ON** until first waveform and number appear
- One-piece Plug & Play consumables
Microstream® Capnography Advantages

**Reliable Technology**
- Fast response time
- 1 mm microbore tubing reduces delay time
- Crisp waveform – longitudinal filter maintains laminar flow
- 0.2 micron Filter (hydrophobic longitudinal hollow fiber filter) prevents liquids from entering into the monitor
Microstream® Capnography Advantages

Flexible for all Patient Populations – *Solution for monitoring neonates*

- 50 ml/min flow rate supports entire patient population – including neonates, compared to other brands that require 3-4 times the sample flow rate (150-200ml/min)

- Does not compete for Neonate tidal volume

- The lower the flow, the less moisture in the sampling line
FilterLine® Solutions for EMS

Non-Intubated

Intubated

Smart Solutions

Smart CapnoLine® Plus/
Smart CapnoLine® Plus $O_2$

FilterLine® Sets

Smart CapnoLine® Plus
with connector
Smart Solutions for Non-intubated Patients

“Microstream® technology allows the accurate measurement of EtCO₂ in the absence of an endotracheal tube.”

- Continuous sampling from both mouth and nose
- Special oral-piece design optimally samples when the patient is mouth breathing
- Increased surface area provides greater sampling accuracy in the presence of low tidal volumes

ASA, 2001. Jay Brodsky, MD Professor of Anesthesia, Stanford University Medical Center, CA, USA.
Smart Solutions for Non-intubated Patients

“Smart CapnoLine®Plus / Smart CapnoLine®Plus O₂”
Oral/nasal FilterLine® for CO₂ measurement and O₂ delivery

- Uni-junction sampling method ensures optimal waveform and ultra-fast response time
- Unique O₂ delivery method reduces CO₂ sampling dilution
- Effective O₂ delivery for both low flow and high flow needs
Microstream® Capnography
A Unique Solution for Non-intubated Patients

- $\text{CO}_2$ sampling/$\text{O}_2$ delivery for non-intubated patients

Small pin holes deliver oxygen around both nose and mouth

Uni-junction™ of sampling ports prevents dilution from supplemental oxygen

Increased surface area provides greater sampling accuracy in the presence of low tidal volume
FilterLine® Sets - Solutions for Intubated Patients

- Easily handles moisture and secretions without water traps
- Able to measure in any position
- Easily switches to non-intubated monitoring without re-calibration of monitor
FilterLine® FAQs

- For use only with monitors using Microstream® technology
- Single patient use, latex free
- Do not attempt to disinfect or flush lines
- Securely connect all components
- Never cut any area of a FilterLine® CO₂ sampling line
- Do not instill medications through the airway adapter
- When suctioning or instilling saline, place monitor into standby
- Never pass a suction catheter or stylet through the intubated airway adapter
- Change the FilterLine® CO₂ sampling line when the monitor displays a CO₂ occlusion message
“Microstream® features:
- Low flow rates
- Reduced dead space
- Lack of moisture-associated occlusion problems, and
- Low power consumption.
Furthermore, it can be used reliably in both intubated and non-intubated patients.”

*Journal of Clinical Monitoring and Computing, August 1999. Baruch Krauss, MD, Division of Emergency Medicine, Boston Children’s Hospital, Instructor in Pediatrics, Harvard Medical School, Boston, Massachusetts, USA.
Capnographic Waveforms

As Diagnostic as an ECG Waveform
Capnographic Waveform

- Normal waveform of one respiratory cycle
- Similar to ECG
  - Height shows amount of CO₂
  - Length depicts time
Capnogram: Phase I

- Phase I occurs during exhalation of air from the anatomic dead space, which normally contains no CO₂.
- This part of the curve is normally flat, providing a steady baseline.
Capnogram: Phase II

- Phase II occurs during alveolar washout and recruitment, with a mixture of dead space and alveolar air being exhaled.
- Phase II normally consists of a steep upward slope.
Phase III is the alveolar plateau, with expired gas coming from the alveoli.

In patients with normal respiratory mechanics, this portion of the curve is flat, with a gentle upward slope.

The highest point on this slope represents the EtCO$_2$ value.
Atmospheric air contains negligible amounts of CO₂.

Phase IV occurs during inspiration, where the EtCO₂ level normally drops rapidly to zero.
- Unless CO₂ is present in the inspired air, as occurs when expired air is rebreathed
- This part of the waveform is a steep, downward slope.
Capnography Waveform

Normal range is 35-45 mm 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

**Normal**

**Hypoventilation**

RR: EtCO₂
Capnography Waveform Patterns

Normal

Hyperventilation

Hypoventilation
Capnography Waveform Question

How would the waveform shape change during an asthma attack?
Bronchoconstriction

- Shark-like in appearance
Asthma

- Studies are looking at the correlation of baseline values when dealing with asthmatics.
- Treatment will then be tailored to what category the patient falls.
Asthma

- Green—initial distress phase with decrease in CO2 levels. Treatment would include MDI and follow up.
- Yellow—moderate distress phase with normal CO2 levels. Treatment includes neb and transport.
- Red—severe distress phase with increased CO2 levels. This is immediate epi SQ, Neb, and ETT.
Bronchospasm Waveform Pattern

- Bronchospasm hampers ventilation
  - Curves upstroke of Phase II
- Characteristic pattern for bronchospasm
  - "Shark Fin" shape to waveform.
Capnography Waveform Patterns

Normal

Bronchospasm
Capnography Waveform Patterns

- Normal
- Hyperventilation
- Hypoventilation
- Bronchospasm
Using Capnography

Airway
Breathing
Circulation
Documentation
Using Capnography

- Documentation
  - Waveforms
    - Initial assessment
    - Changes with treatment
  - EtCO₂ values
    - Trends over time
Capnography Applications on Intubated Patients

- Confirm correct placement of ET tube
- Detect changes in ET tube position immediately
- Resuscitation
  - Assess adequacy of chest compressions
  - Detect ROSC
  - Objective data for decision to cease resuscitation
- Optimize ventilation of patients
- Document, document, document
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 can be unreliable
Confirm ET Tube Placement

“The presence of exhaled CO₂ indicates proper tracheal tube placement.”

“...end-tidal CO₂ monitors can confirm successful tracheal tube placement within seconds of an intubation attempt”

Confirm ET Tube Placement

- 108 patients intubated in the Field
  - 52 trauma patients
  - 56 medical patients
- ET tube placement checked on arrival at the ED
- 27 patients (25%) had improperly placed ET tube
  - 18 were in the esophagus
  - 9 in oropharynx with tip above the cords

Confirm ET Tube Placement

“All endotracheal intubations must be accompanied by an objective confirmation...The optimal method of measurement is quantitative capnography and its use on all intubated patients.” p-277

Confirm ET Tube Placement

Capnography provides

- Documentation of correct placement
- Ongoing documentation over time through the trending printout
- Documentation of correct position at ED arrival
Transferred to ED at 12:25
Confirm ET Tube Placement

Study in neonates
- 100 intubations
- 40 were esophageal
- Capnography identified 39 of the 40
- Mean time to detection of esophageal intubation
  - 1.6 seconds with capnography
  - 97 seconds with clinical signs.

Airway – Rescue Devices

Combitube

LMA
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
- CO$_2$ detection will disappear 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
Detect ET Tube Displacement

“Continuous capnography monitoring devices can identify and signal a fall in exhaled CO2 consistent with tracheal tube dislodgement. This may be very helpful in emergencies when clinicians have other responsibilities.” p-140

Detect ET Tube Displacement

- Capnography
  - *immediately* detects ET tube displacement
Capnography in Cardio Pulmonary Resuscitation

- Assess chest compressions
- Early detection of ROSC
- Objective data for decision to cease resuscitation
CPR, Cardiac Output, and EtCO2

Reference: Capnography.com
CPR: Assess Chest Compressions

- Capnography provides non-invasive method for monitoring blood flow generated by CPR
- **Airway** - open with ET tube
- **Breathing** - controlled and stable
- **Circulation** - cardiac output directly related to changes in EtCO$_2$
CPR: Assess Chest Compressions

- Increase in EtCO$_2$ has been shown to correlate with:
  - A fresh rescuer at a faster compression rate
  - A new rescuer during CPR with no change in rate
  - Mechanical compressions

Better compressions lead to higher ETCO2 levels

CPR: Assess Chest Compressions

Use feedback from ETCO2 to depth/rate/force of chest compressions during CPR.
90 prehospital patients intubated in the field
16 survivors
In 13 survivors a rapid rise on CO\textsubscript{2} production was the earliest indicator of ROSC.
- Before a palpable pulse
- Prior to blood pressure

CPR: Detect ROSC
ETCO2 DURING CPR

Onset of arrest → ETCO2 decreases

During CPR → ETCO2 increases slightly

ROSC → ETCO2 markedly increases

ROSC (cont’d) → ETCO2 falls slightly

Dependent on down time and preexisting conditions
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

- 90 victims of prehospital cardiac arrest with PEA
- EtCO2 in ROSC was much higher after 20 minutes
  - ROSC vs No ROSC
  - Initial: 10.9±4.9 vs 11.7±6.6  \(P=0.672\) (NS)
  - 20 min: 31.0±5.3 vs 33.9±2.8  \(P<=0.0001\)

- 100% mortality if unable to achieve an EtCO2 of 10 mm Hg after 20 minutes

Optimize Ventilation

- Use capnography to titrate EtCO$_2$ levels in patients sensitive to fluctuations
- Patients with suspected intracranial pressure (ICP)
  - Head trauma
  - Stroke
  - Brain tumors
  - Brain infections
Optimize Ventilation

- Monitor ventilations with capnography to maintain appropriate and stable CO₂ levels
- Follow local protocols and medical direction
Non-Intubated Patients

- Objective Assessment of Respiratory Complaints
  - Asthma
  - COPD vs. CHF
- Response to Treatment of Pain
- Assessment of Airway & Ventilatory Status
  - Seizure
  - Intoxication
  - Overdose
- Perfusion Assessment
  - Pacing (Electrical vs. Mechanical Capture)
  - Stable vs. Unstable tachycardia's
  - PEA vs. rhythm with low perfusion
Case Presentations
78 y/o Male, short of breath Hx. Of CHF and COPD

Patient treated with Albuterol, Solu-Medrol and Magnesium Sulfate.
66 y/o female, hx of COPD and CHF, acute onset of CP and Shortness of Breath

Patient placed on CPAP, treated with NTG, Lasix and Morphine. (Above strip was with CPAP in place)
4 y/o female, sister has Asthma and mom administrated her sister’s MDI. RR 46, PR 146

Is there Bronchoconstriction present?
10 y/o female hx of Asthma, School nurse treated with 2 neb. treatments.

Is there Bronchoconstriction present?
89 y/o male called 911 for his wife who fell, he c/o dyspnea. Hx of COPD.

Is there Bronchoconstriction present?
2 year old with special needs having a seizure

Does the patient have an airway and is she ventilating adequately?
60 y/o CPR in progress, rhythm change noted

No palpable pulses, how can we determine if there is perfusion?
CPR is stopped, Ventilations are continued.

Is there perfusion? Why or Why Not
48 y/o male Narcotic OD. Code Summary

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<th>Time</th>
<th>Event</th>
<th>HR</th>
<th>SpO2</th>
<th>PR</th>
<th>EtCO2 (mmHg)</th>
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Are there any issues present?
48 y/o male Narcotic OD. Code Summary

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Are there any issues present?
Trend Summary
63 y/o female, found unresponsive in bed 1 hour after lunch. Hx CVA and IDDM

- VS – Initial
  - P-86, R-14, BP 112/76, GCS-8
- VS – 8 minutes later
  - P-88, R-40, ETCO$_2$ – 20, GCS-8
- VS – 17 minutes into patient care
  - P-84, R-14, BP 142/112, GCS-8, ETCO$_2$ – 30
- VS – 24 minutes into patient care
  - P-86, R-36, BP 150/120, GCS-8, ETCO$_2$ – 20
- Pulse Ox 100% on NRB entire time
Was the patient ventilating adequately during care?

What type of breathing pattern has been described and documented?
Detection of Metabolic Acidosis

- Assesses metabolic status providing information on how effectively CO2 is being produced by cellular metabolism.
- Recent studies have shown that EtCO2 and serum bicarbonate (HCO3) are linearly correlated in diabetes.
- Can be used as an indicator of metabolic acidosis in these patients.
Capnography in Diabetics

As the patient becomes acidotic, HCO3 decreases and a compensatory respiratory alkalosis develops with an increase in minute ventilation and a resultant decrease in EtCO2.

The more acidotic, the lower the HCO3, the higher the respiratory rate and the lower the EtCO2.
Capnography in Diabetes

- **Ketoacidosis**
  - metabolic acidosis
  - compensatory tachypnea, low EtCO$_2$

- **HHNC**
  - Nonacidotic
  - normal respiratory rate, normal EtCO$_2$
Why this Works

- $\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2$

- As the body uses up its stores of Bicarb to rid the acid it loses its ability to transport Carbon Dioxide
- So as Dioxide levels fall it correlates to the lack of bicarb.....patient is acidotic.
86 year-old male “Something is not right.”
Capnography and Perfusion

How is the patient’s perfusion status?
Cardioversion

CO₂ Initializing post Defibrillation and Cardioversion
How is the patient’s perfusion status?
Trend Summary
67 year-old male Cardiac Arrest – COPD

Is the tube in the correct place?

How is the patient’s perfusion status?
Perfusion Status???

Do we need to continue chest compressions?
Trend Summary
Other Waveforms
Abnormal Waveforms

- Gradual increase in $\text{EtCO}_2$
  - Rising body temperature
  - Hypoventilation
  - Increased metabolism
Abnormal Waveforms

Sustained low EtCO₂ with a good plateau indicates either hyperventilation or a large physiological dead space ventilation, resulting in a widened a-ADCO₂.

- Pulmonary Emboli
- Hypovolemia
- Hyperventilation
- COPD resulting in alveolar over-distension
- Excessive level of PEEP
Curare Cleft
Emphysema

- The slope of phase III can be reversed in patients with emphysema where there is marked destruction of alveolar capillary membranes and reduced gas exchange
Where to Get More Information

- **Medtronic Physio-Control**
  - Local Sales Representative
  - www.physiocontrol.com
- www.oridion.com
- www.capnography.com
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