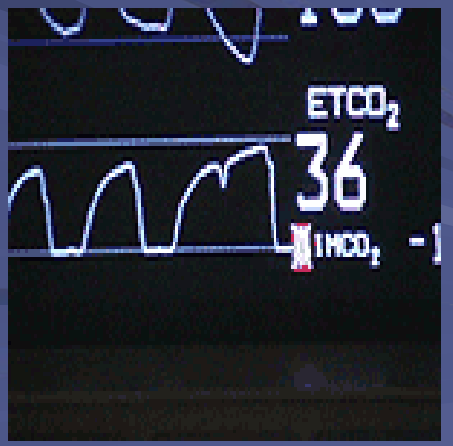
Capnography

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.



CAPNOGRAPHY

- 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

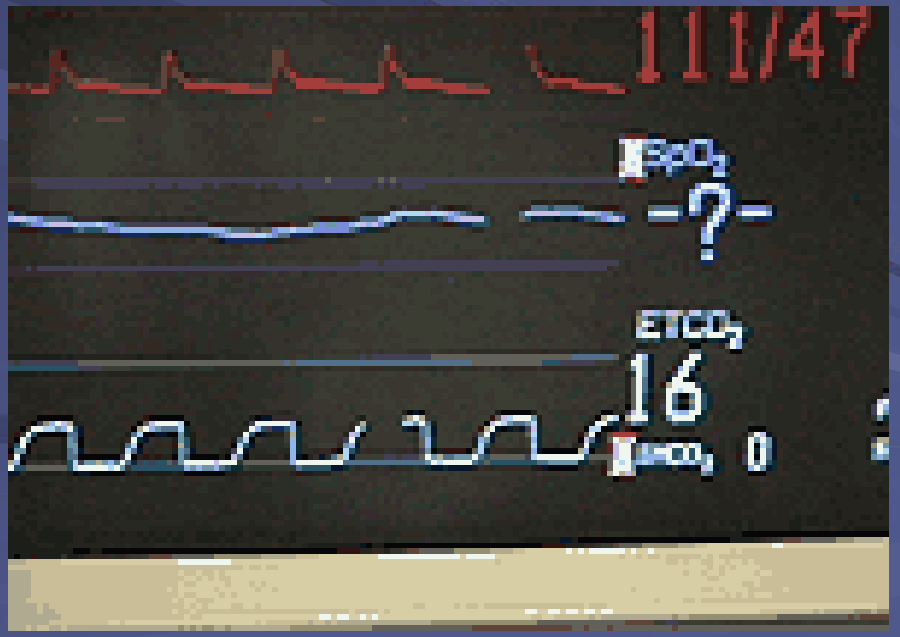
- Measurement and display of both $ETCO_2$ value and capnogram (CO_2 waveform)
- Measured by a capnograph

Capnometry

- Measurement and display of $ETCO_2$ value (no waveform)
- Measured by a capnometer

Pulmonary Physiology

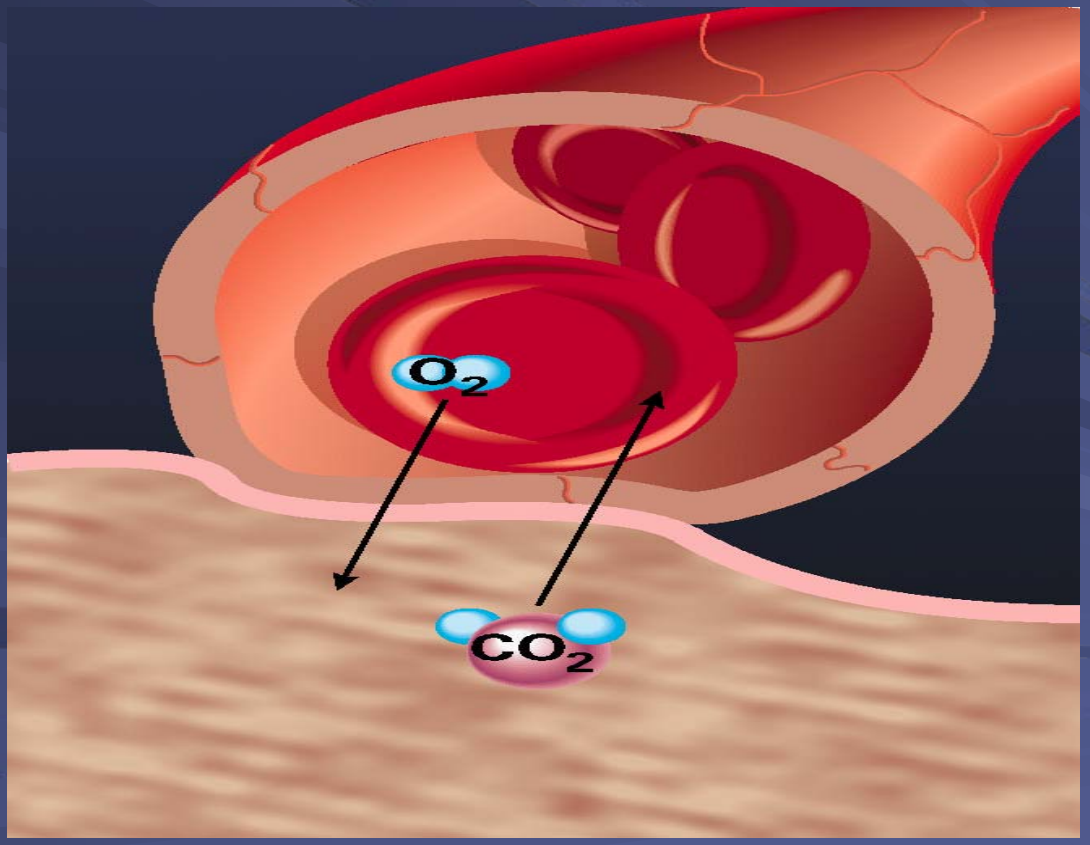
- Oxygenation vs Ventilation
- Metabolic Respiration
  - The EMS version!



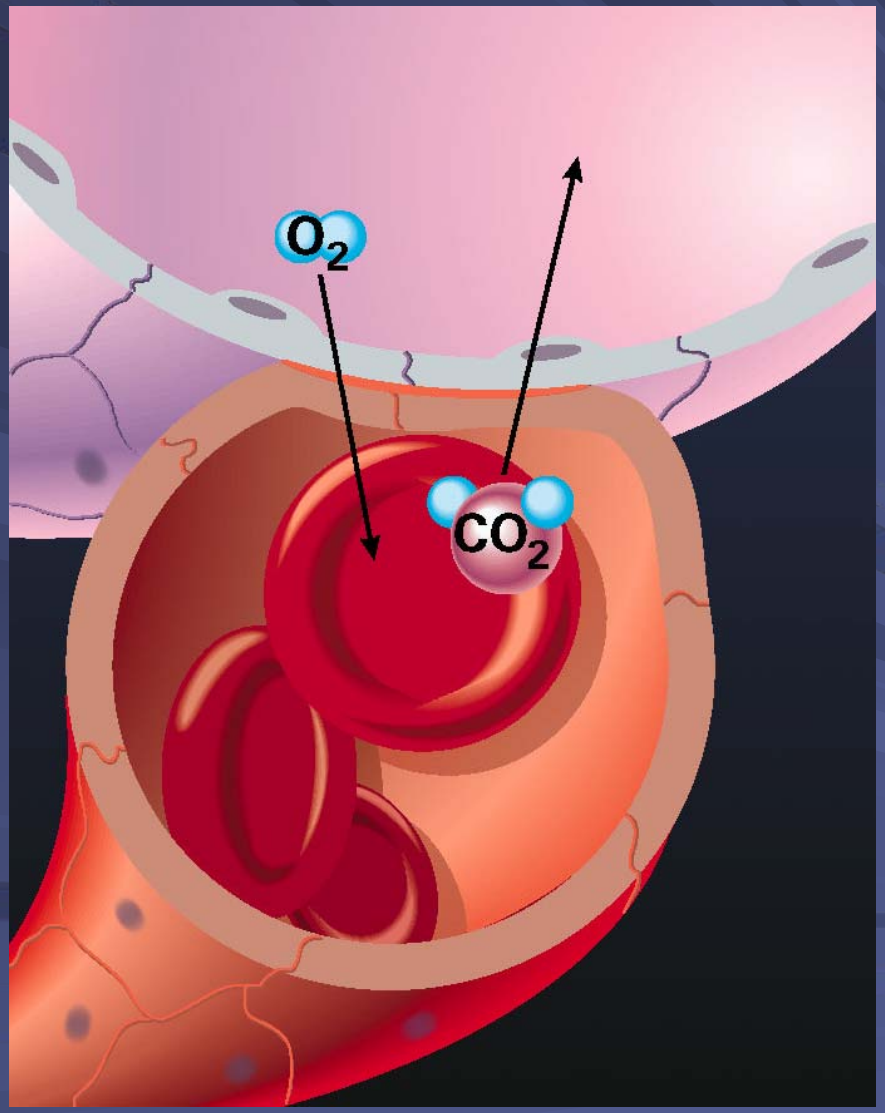
- Oxygenation – How we get oxygen to the tissues
- Ventilation (the movement of air) – How we get rid of carbon dioxide.

Cellular Respiration

- Glucose (sugar) + Oxygen → Carbon dioxide + Water + Energy (as ATP)



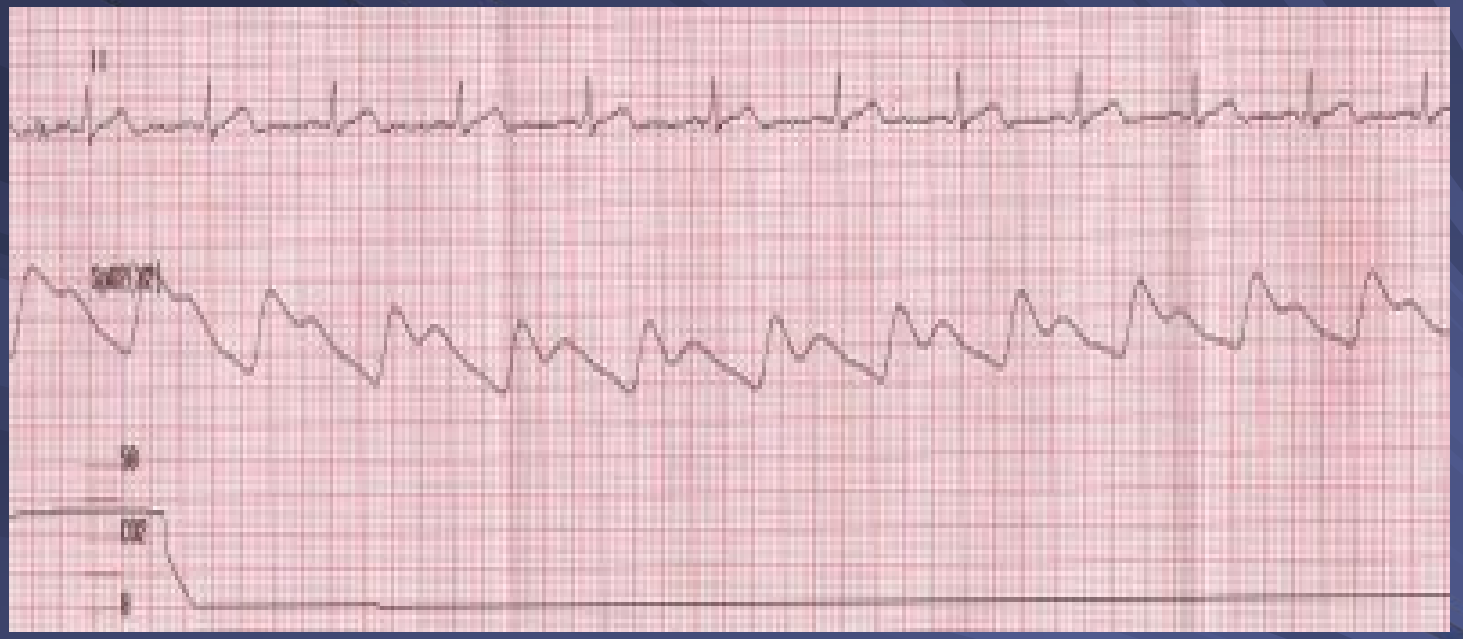
Alveolar Respiration



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



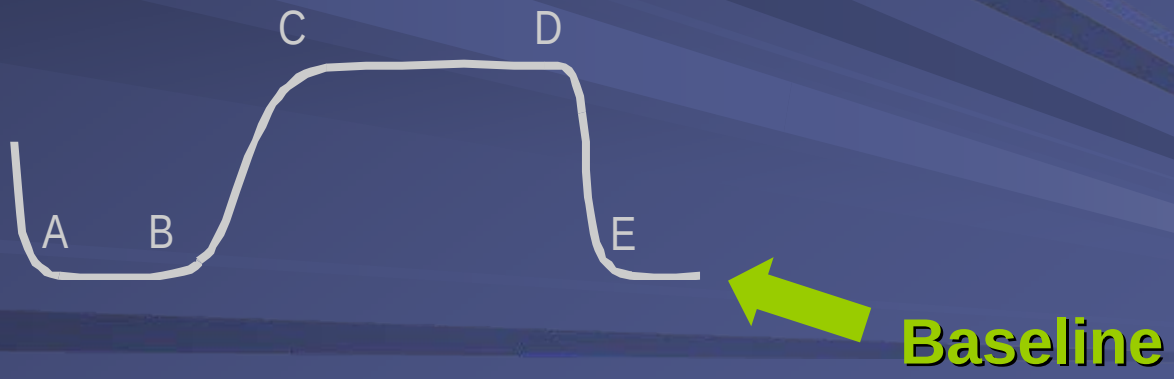
- Good pulse….good Spo2….No Capnography!

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 the airway
  - Provides a breath-to-breath status of ventilation

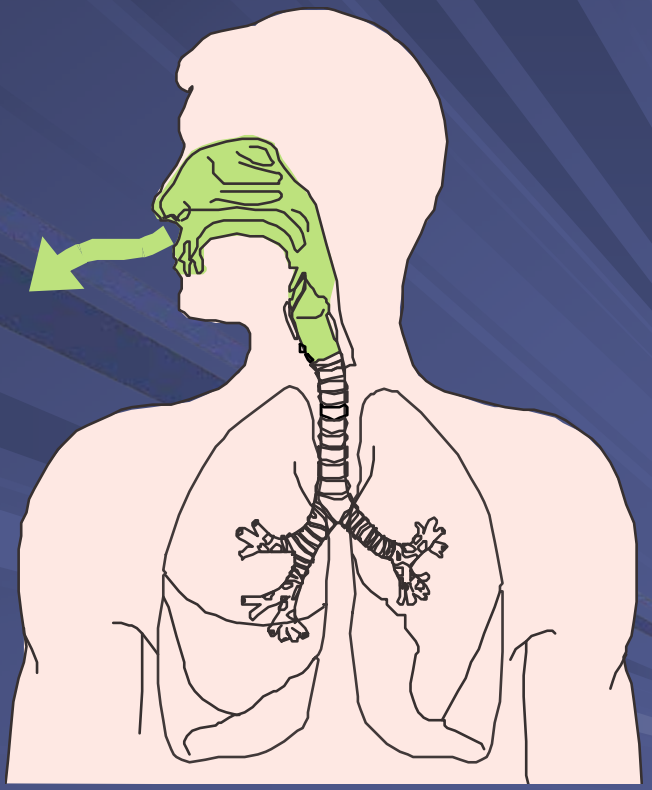
Capnographic Waveform

- 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 CO_2 present
- Air from trachea, posterior pharynx, mouth and nose
  - No gas exchange occurs there
  - Called “dead space”

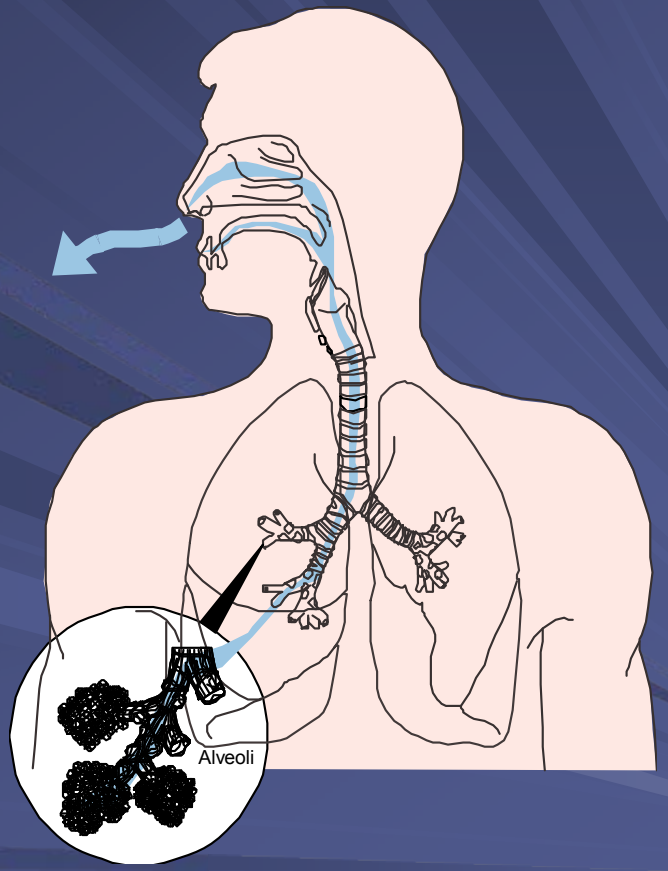


Capnogram Phase I
Baseline

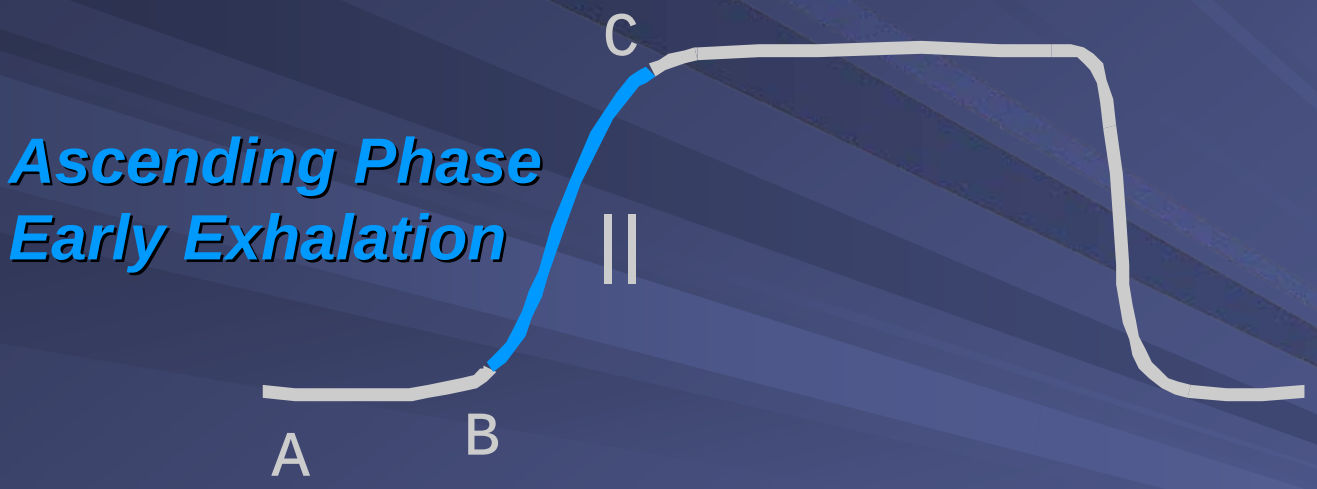
Beginning of exhalation

Capnogram Phase II
Ascending Phase

- 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 CO_2
- CO_2 now present and detected in exhaled air



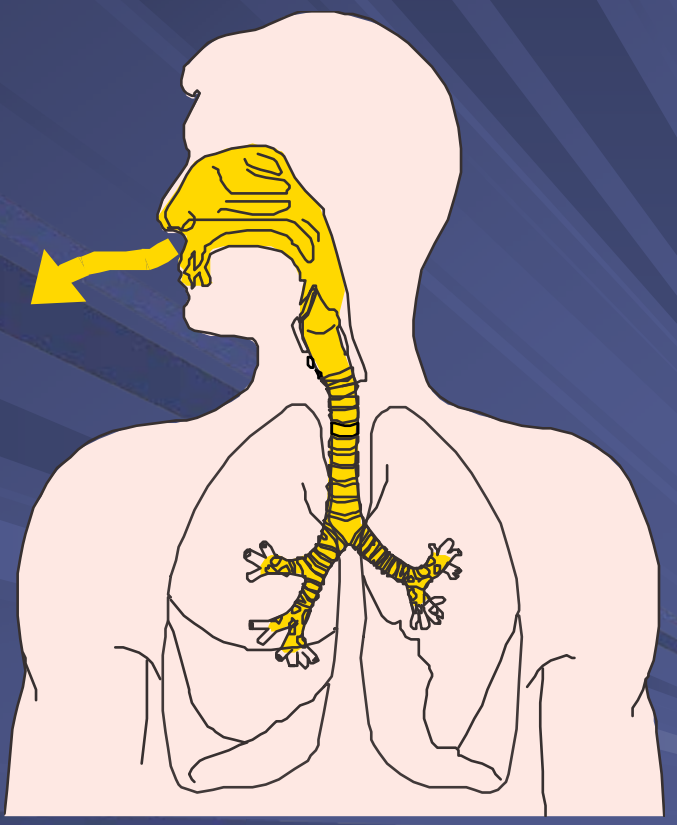
Capnogram Phase II
Ascending Phase



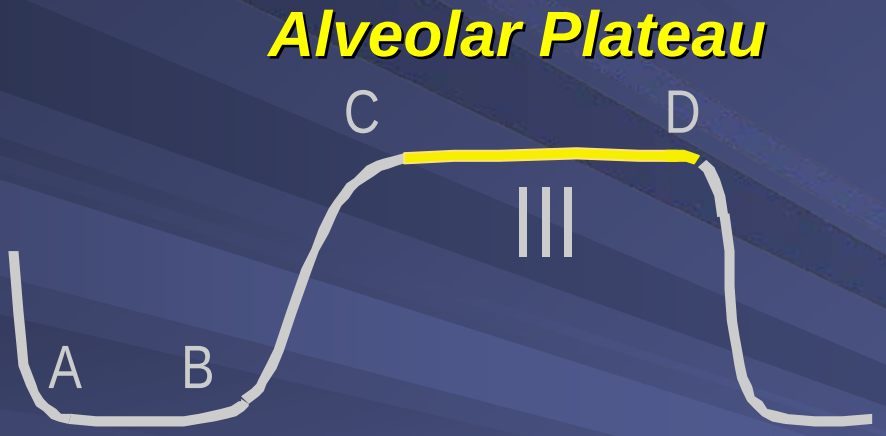
CO_2 present and increasing in exhaled air

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

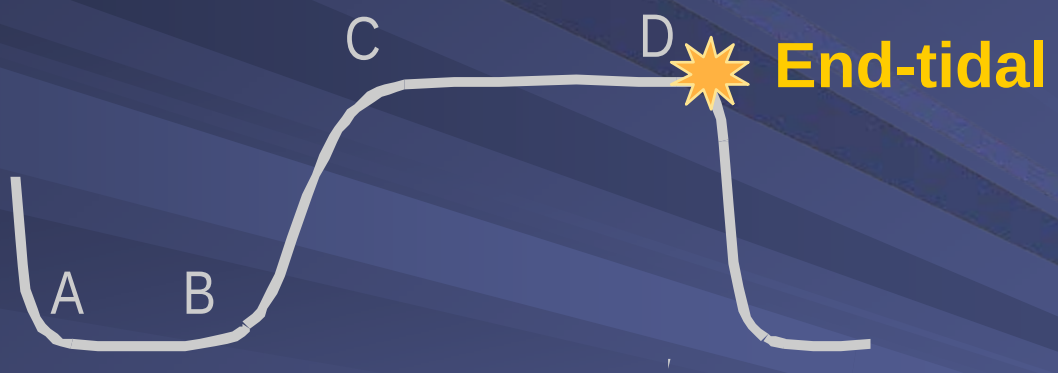


CO_2 exhalation wave plateaus

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
  - Normal is relative NOT absolute

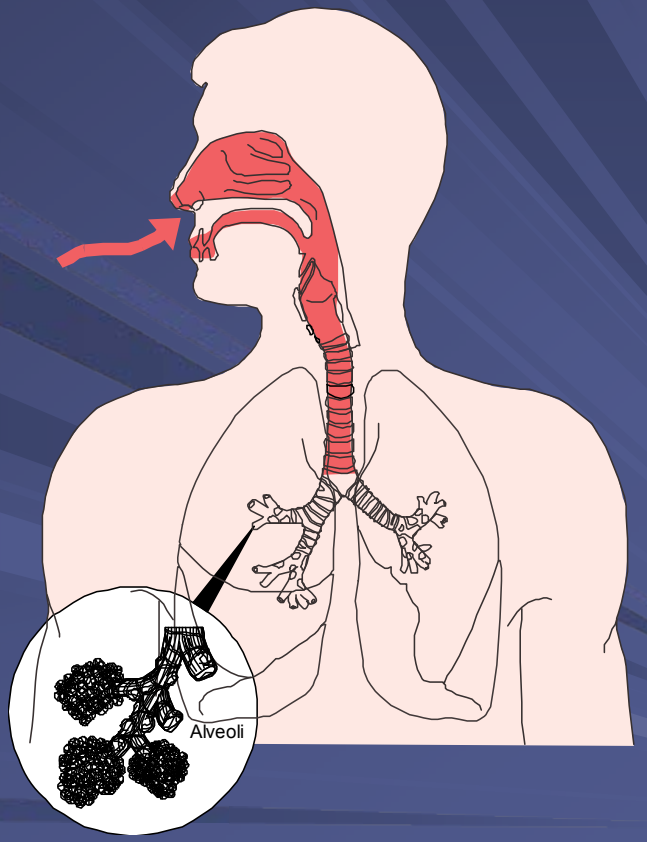
Capnogram Phase III
End-Tidal



End of the the wave of exhalation

Capnogram Phase IV
Descending Phase

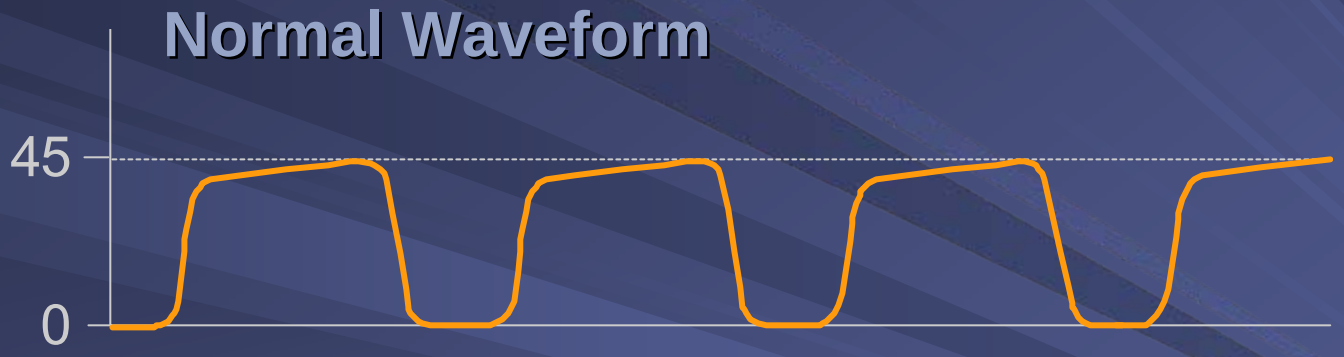
- Inhalation begins
- Oxygen fills airway
- CO_2 level quickly drops to zero



Capnogram Phase IV
Descending Phase

Inspiratory downstroke returns to baseline

Capnography Waveform



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

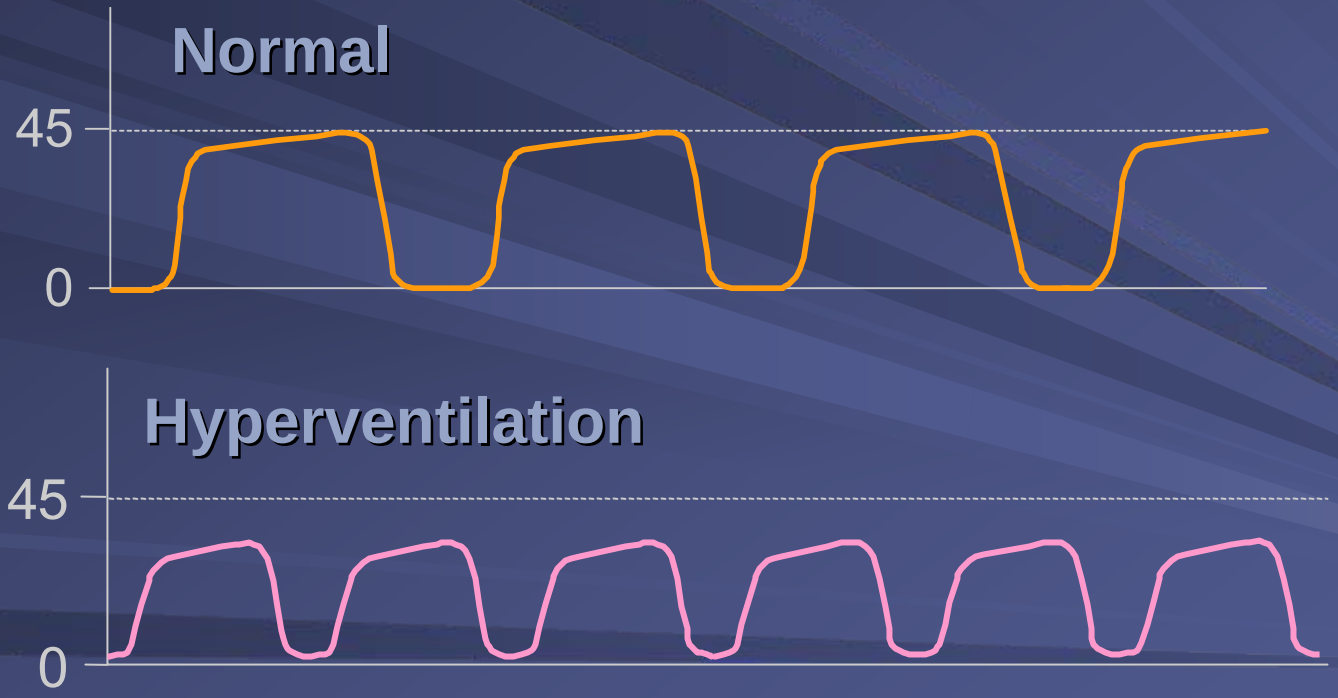
Note: This is Relative NOT absolute

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 ↑: $EtCO_2$ ↓

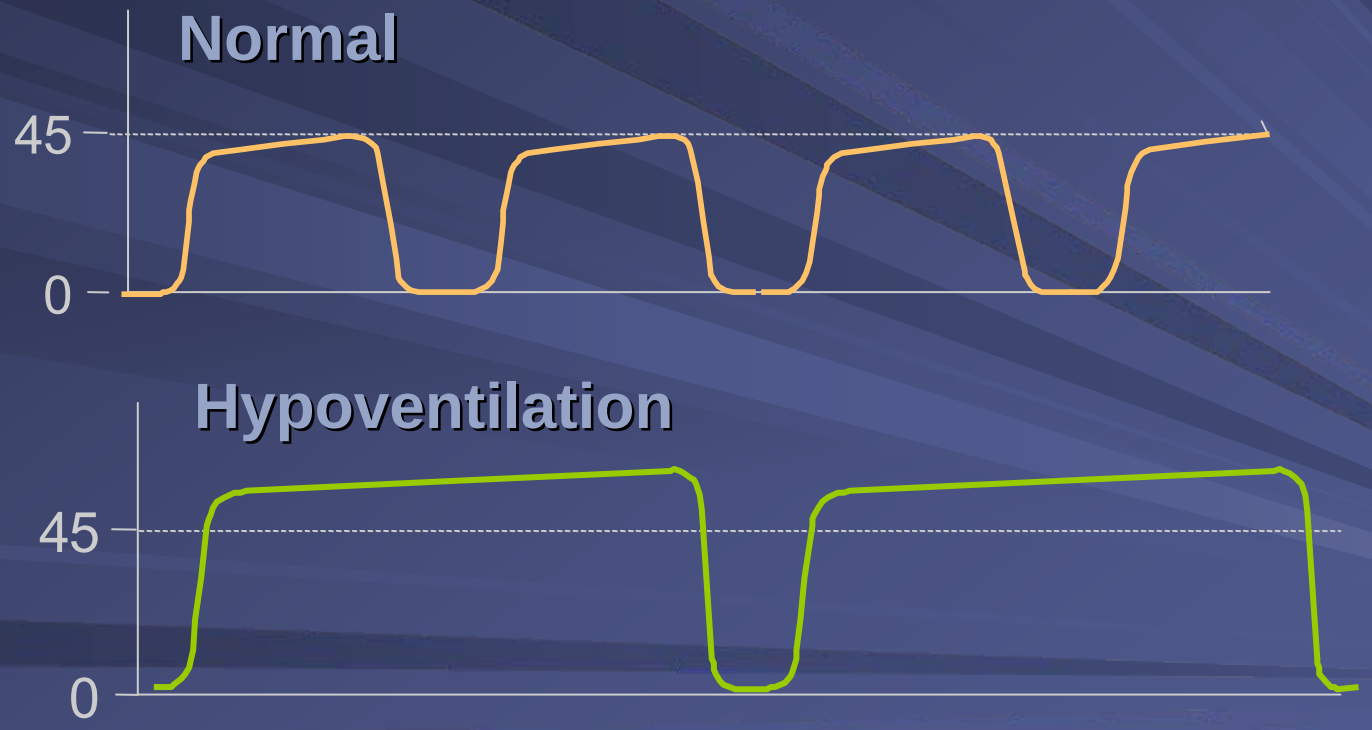


Capnography Waveform Question

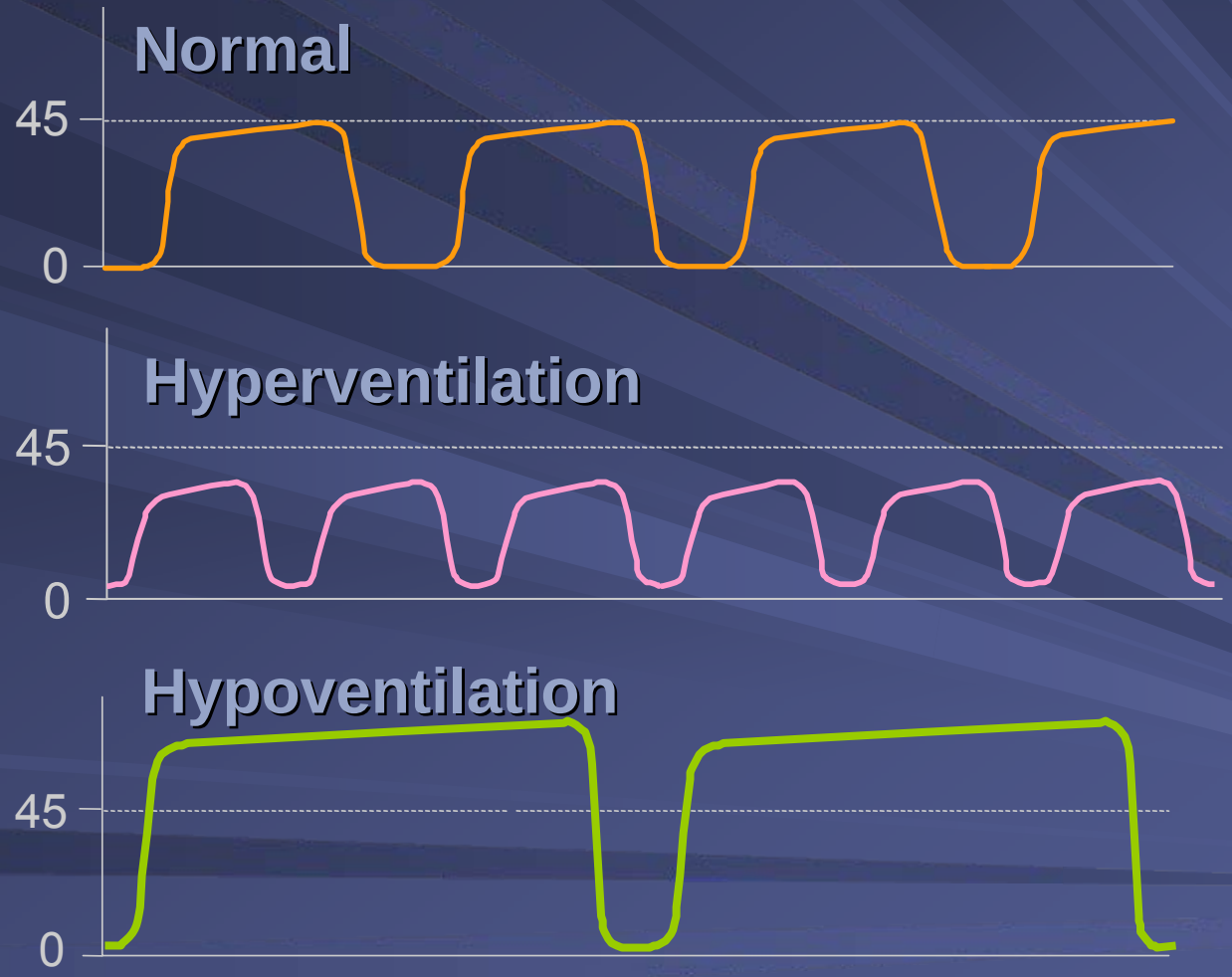
- How would your capnogram change if you intentionally decreased your respiratory rate to 8?
  - Frequency
  - Duration
  - Height
  - Shape

Hypoventilation

RR ↓ : $EtCO_2$ ↑



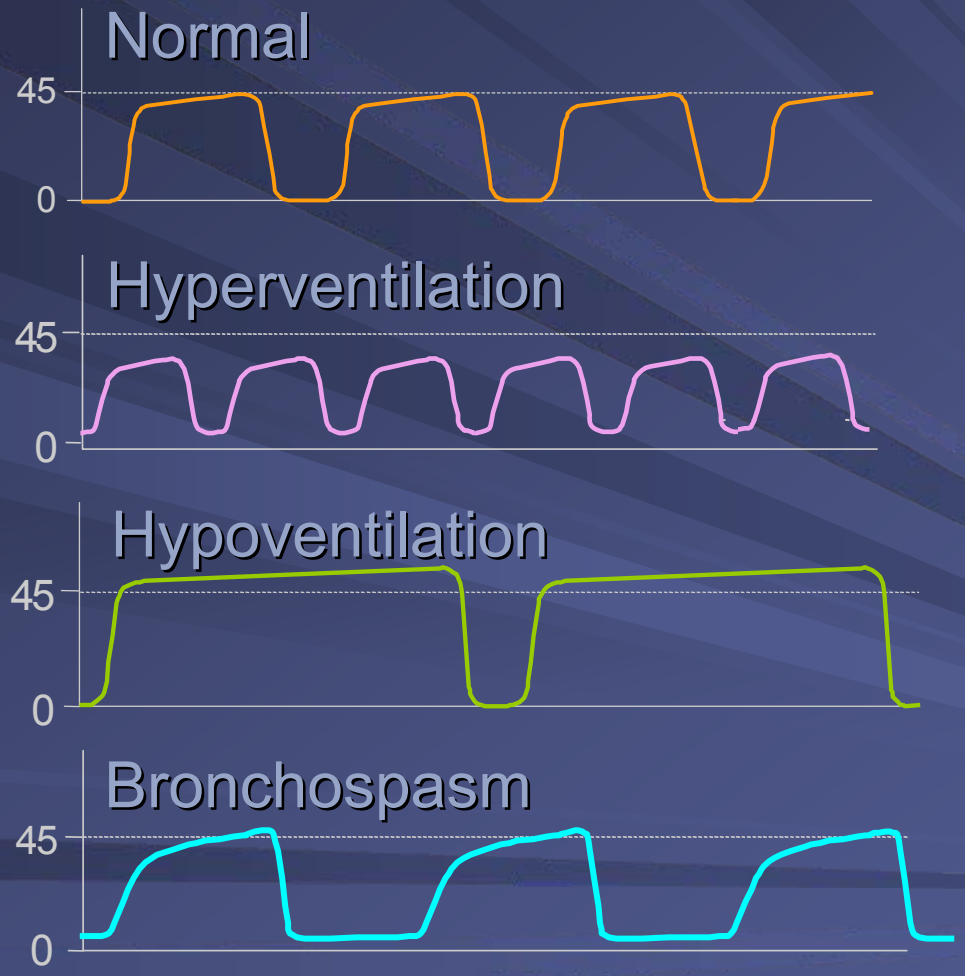
Capnography Waveform Patterns



Introduction to Capnography Summary

- Capnographic waveform has four phases
- The highest CO_2 concentration is at the end of alveolar plateau
  - End-tidal CO_2
  - Normal $EtCO_2$ range is 35-45mmHg
- Several conditions can be immediately detected with capnography

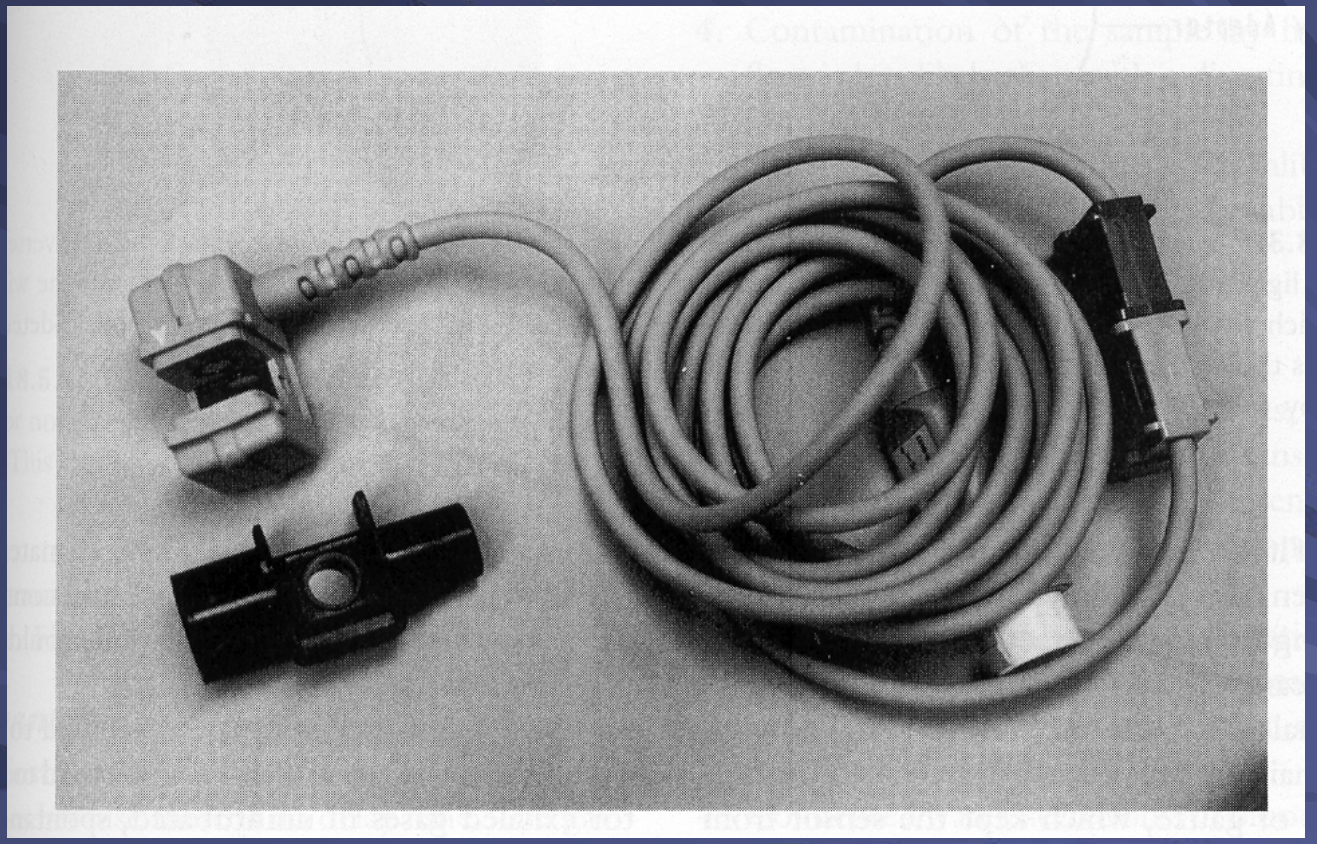
Capnography Waveform Patterns



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

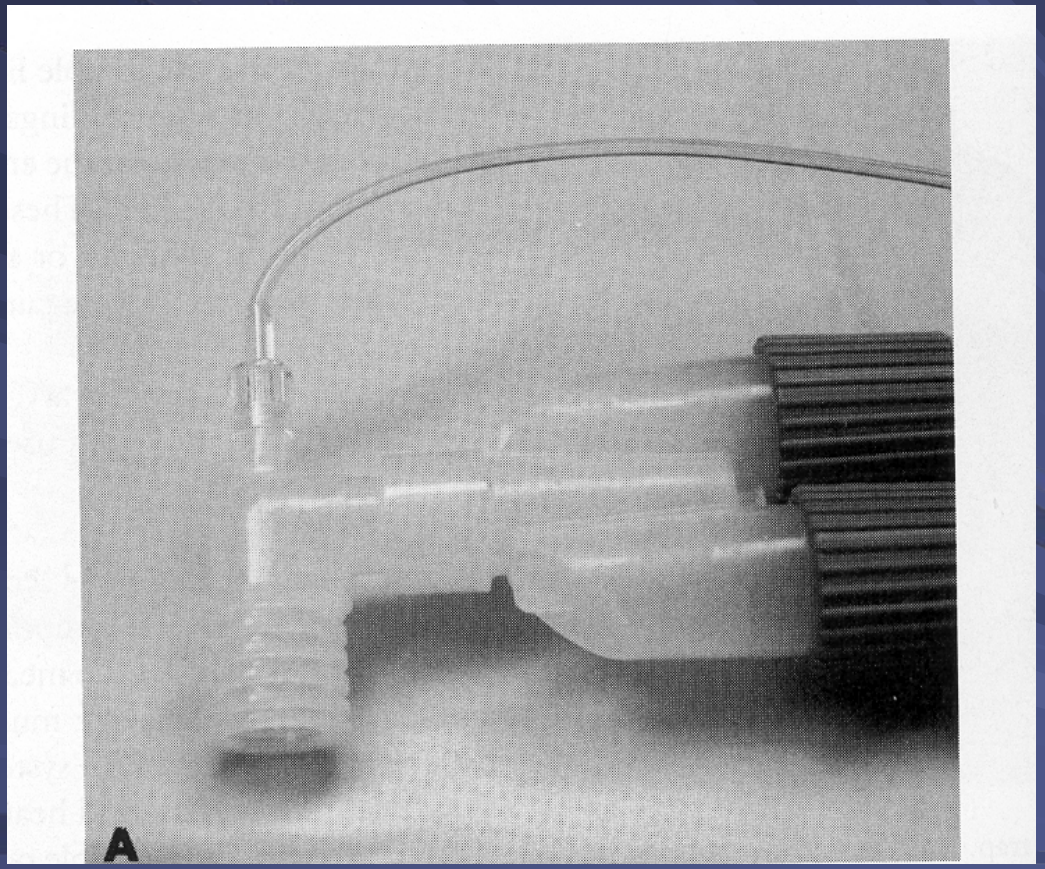
Mainstream Analyzer



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

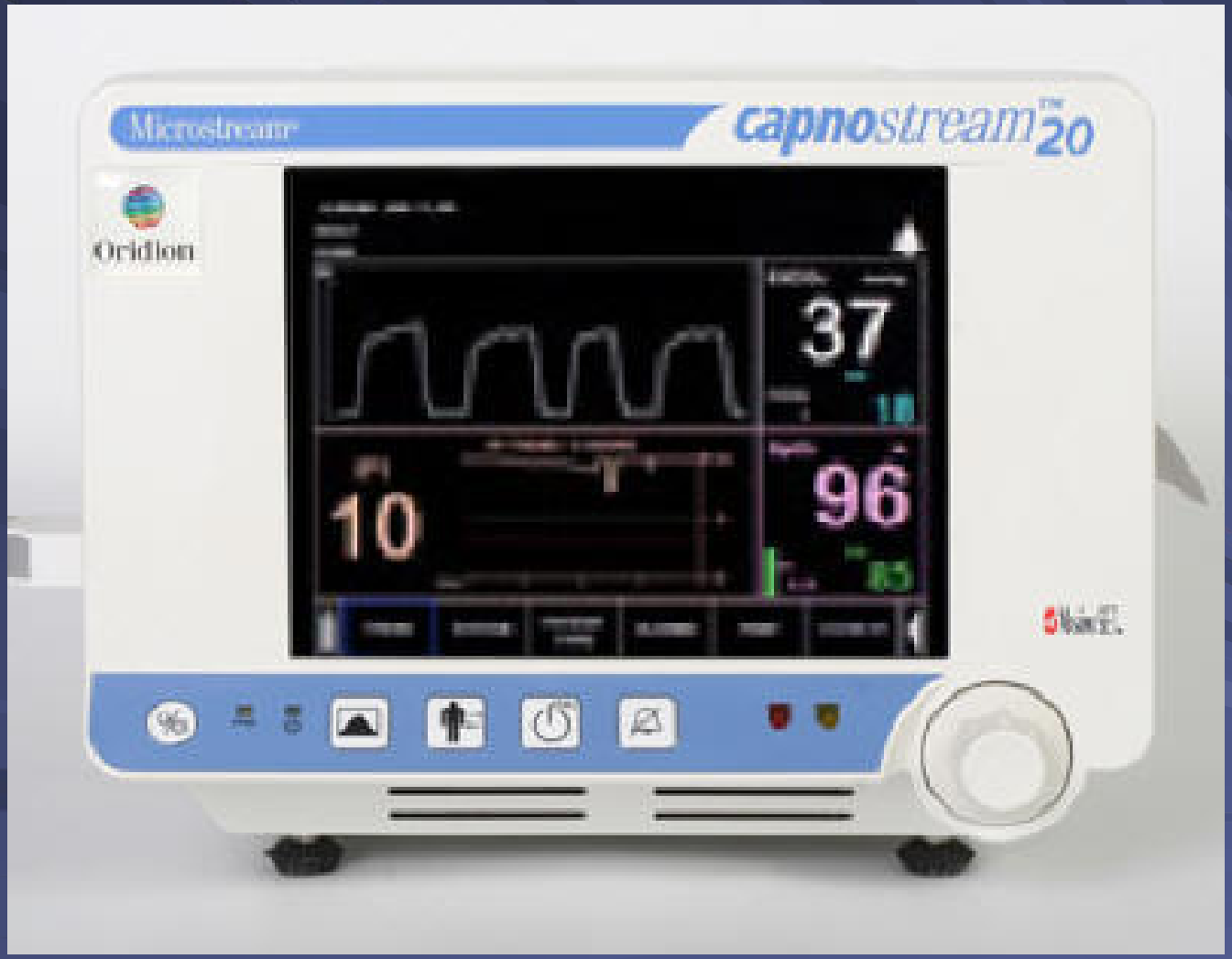
Zoll Capnostat Sensor

Displays


NIBP 188
110
CO2 40
RR 32
SpO2 % 92
ECG x1 118
II
ART
P2
ECG
SpO2
T1 °F
T50
CO2
0
06:53
Param | Traces | ID # | Alarms | 12 Lead

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 $ETCO_2$ Works

- $ETCO_2$ monitoring determines the CO_2 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 CO_2 concentration
- A monitor converts this data to a CO_2 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 CO_2 is high.
  - Hypoventilation
  - Respiratory Acidosis
- If the number is < 35, the CO_2 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

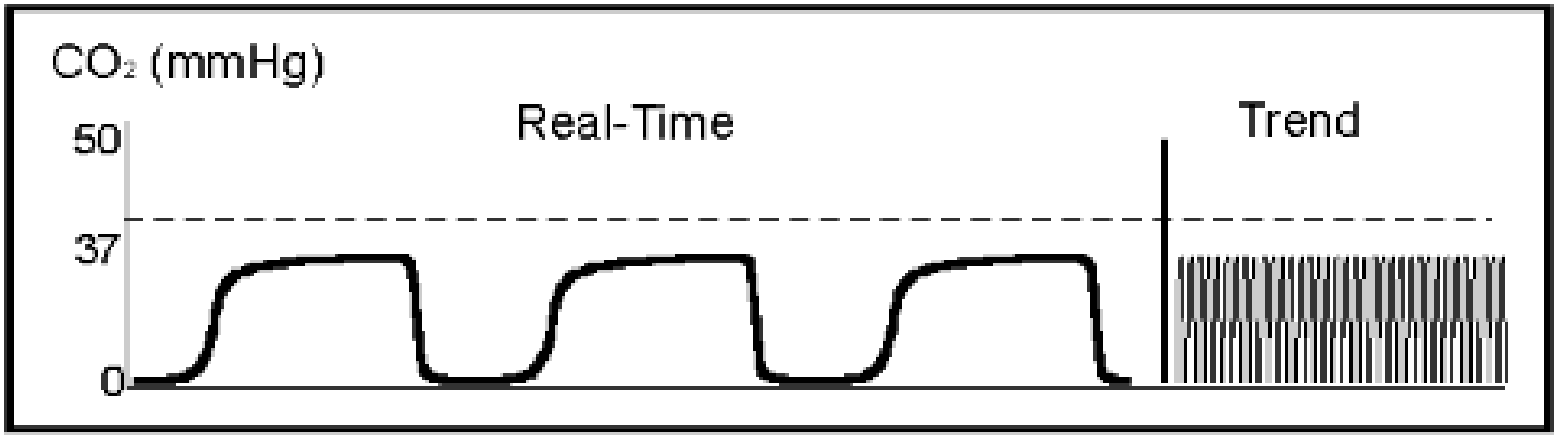
- ET tube placement in esophagus may briefly detect CO_2
  - Following carbonated beverage ingestion
  - When gastric distention was produced by mouth to mouth ventilation
- Residual CO_2 will be washed out after 6 positive pressure breaths

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

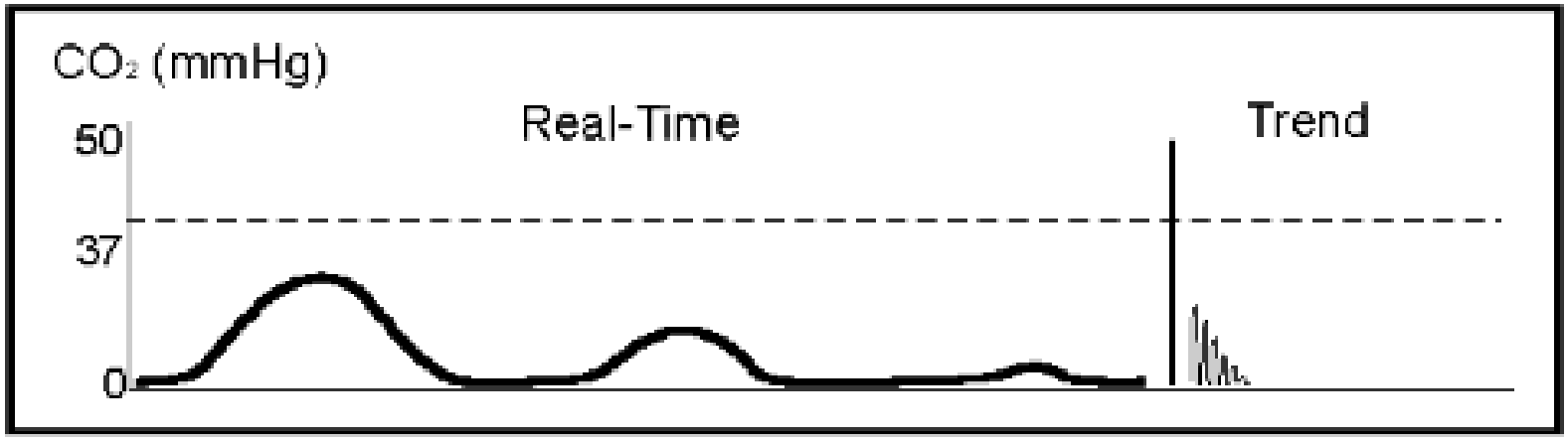
These methods are subjective and unreliable—and delayed

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

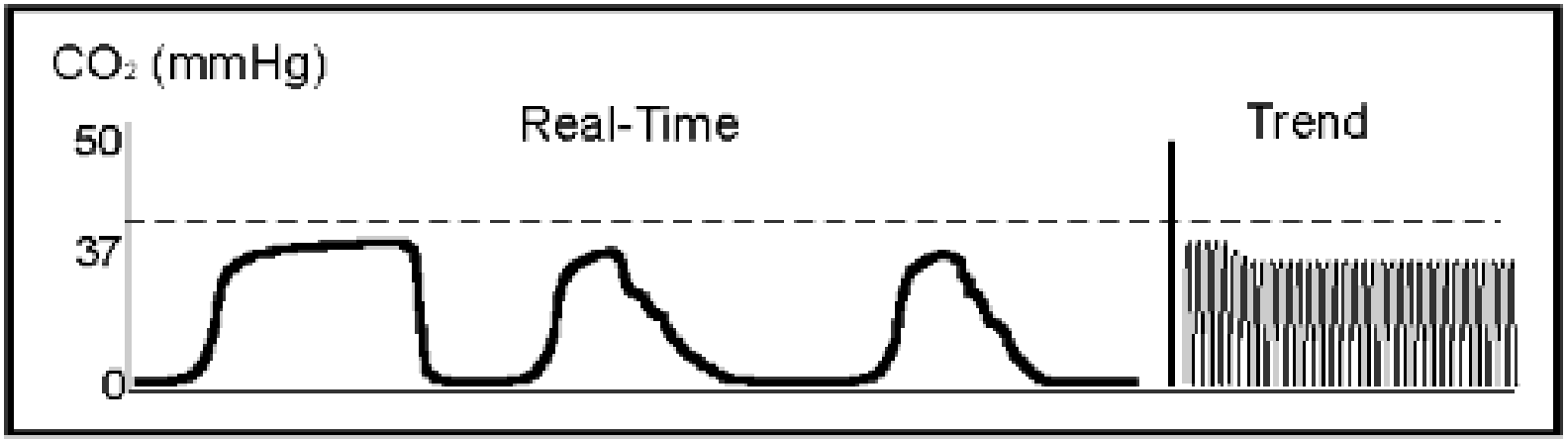
Endotracheal Tube in Esophagus



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 CO_2 is present

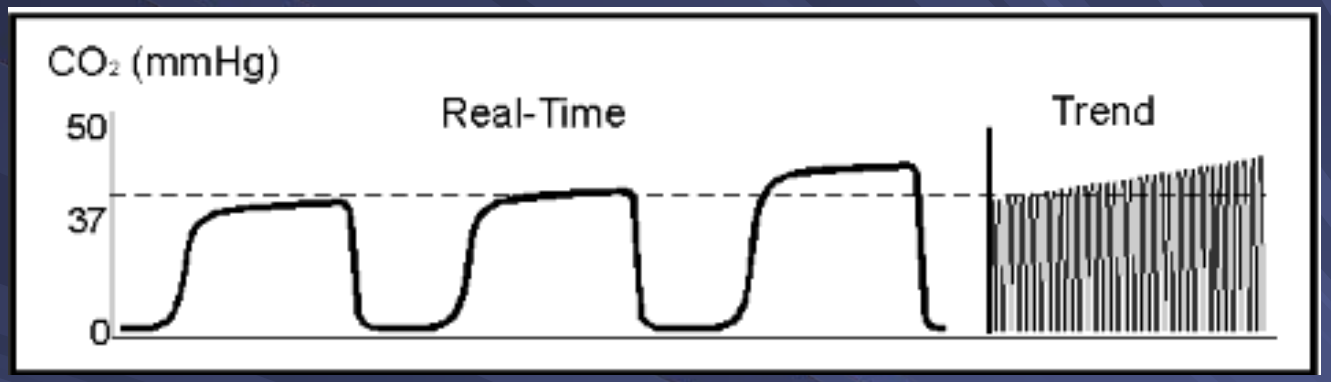
Inadequate Seal Around ET Tube



Possible Causes:

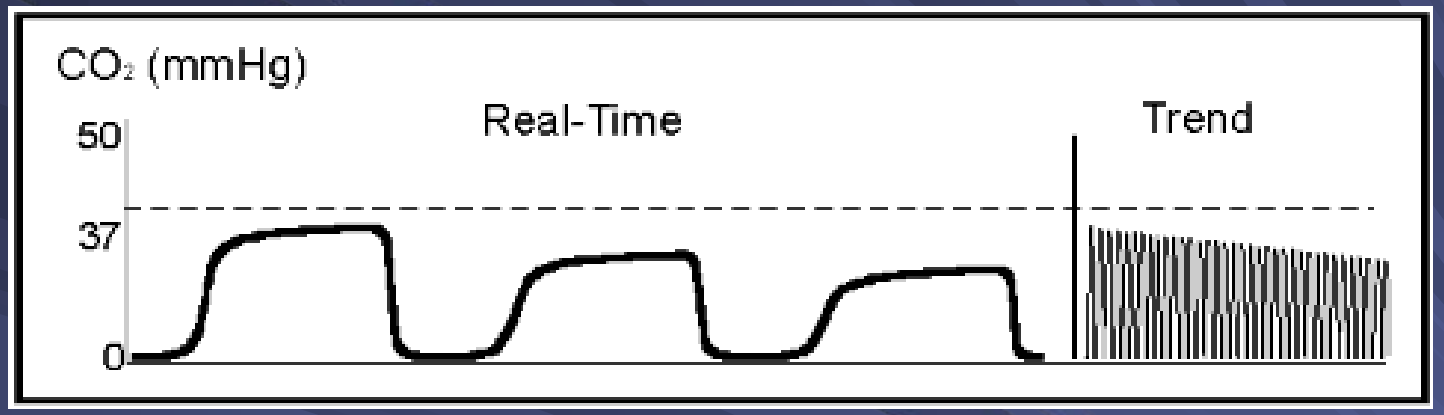
- Leaky or deflated endotracheal or tracheostomy cuff
- Artificial airway is too small for the patient
- **Connections on sample tubing loose**

Increasing $ETCO_2$



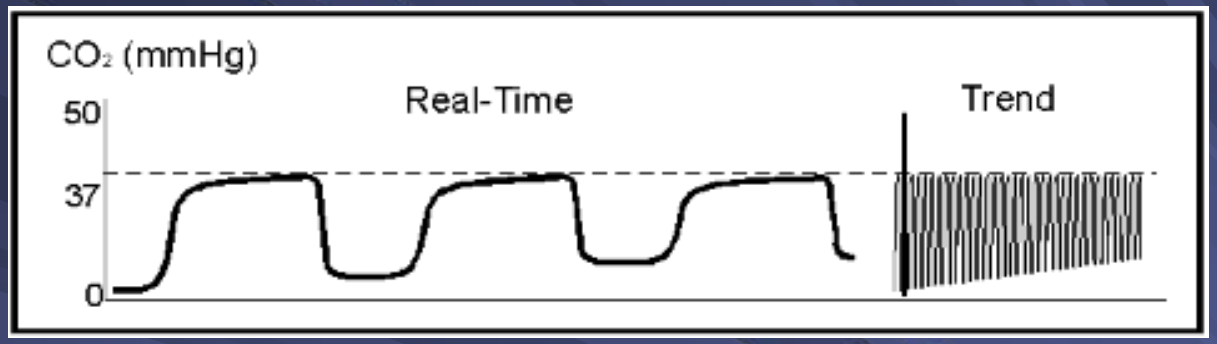
- Hypoventilation (decrease RR or TV)
- Increase in metabolic rate
- Increase in body temperature
- Sudden increase in blood pressure

Decreasing $ETCO_2$



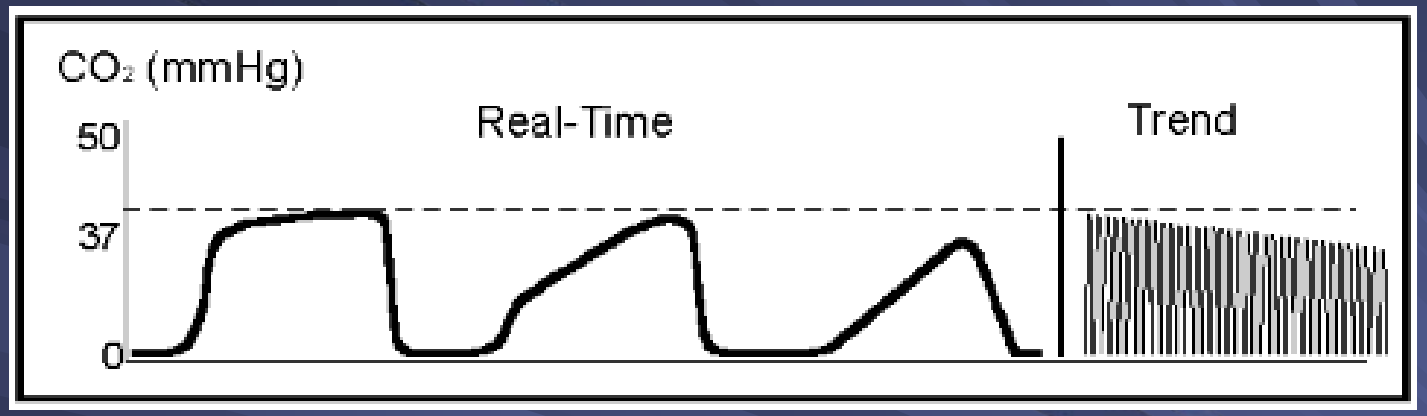
- Gradual
  - Hyperventilation (increase RR or TV)
  - Decrease in metabolic rate
  - Decrease in body temperature
- Rapid
  - Embolism (air or thrombus)
  - Sudden hypotension
  - Circulatory arrest

Increase in Inspired CO2 (Rise in Baseline)



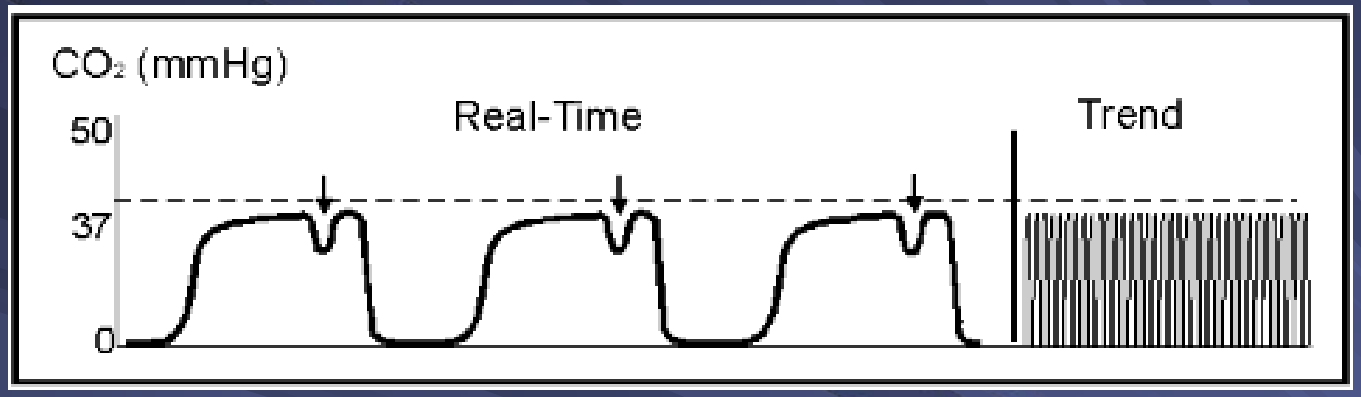
- CO2 absorbent exhausted
- Faulty expiratory valve
- Calibration error in monitor
- Water in analyzer

Loss of Plateau / Sloping of ETCO2 Waveform



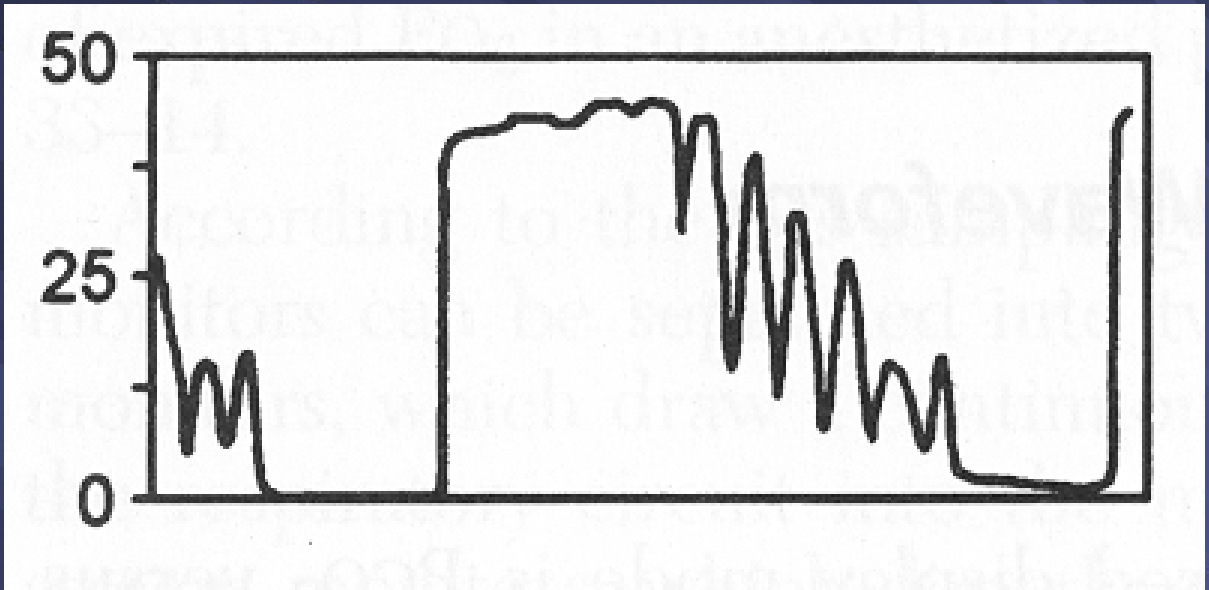
- Obstruction of expiration (asthma, COPD, bronchospasm)
- No plateau is reached prior to next inspiration
- Kinked endotracheal tube

Cleft in Phase III of Waveform



- Patient is inspiring during exhalation phase of mechanical ventilation
- PaCO2 increasing cause spontaneous respiration
- Increasing pain

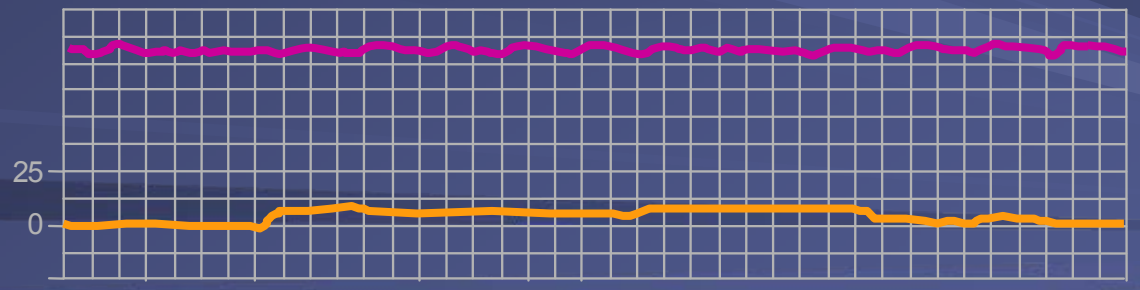
Cardiogenic Oscillations



- 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?

PE?

Bronchitis?

Pneumonia?

Cardiac ischemia?

CHF?

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

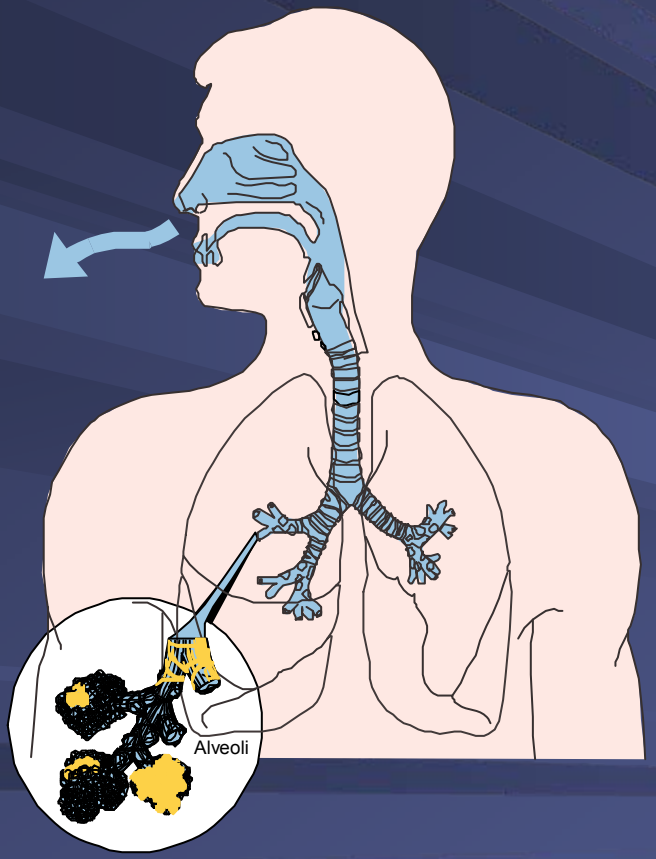
The Non-intubated Patient Capnography Applications

- 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)

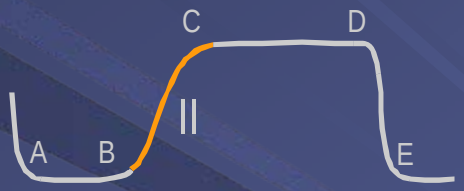
Capnography in Bronchospastic Conditions



- Air trapped due to irregularities in airways
- Uneven emptying of alveolar gas
  - Dilutes exhaled CO_2
  - Slower rise in CO_2 concentration during exhalation

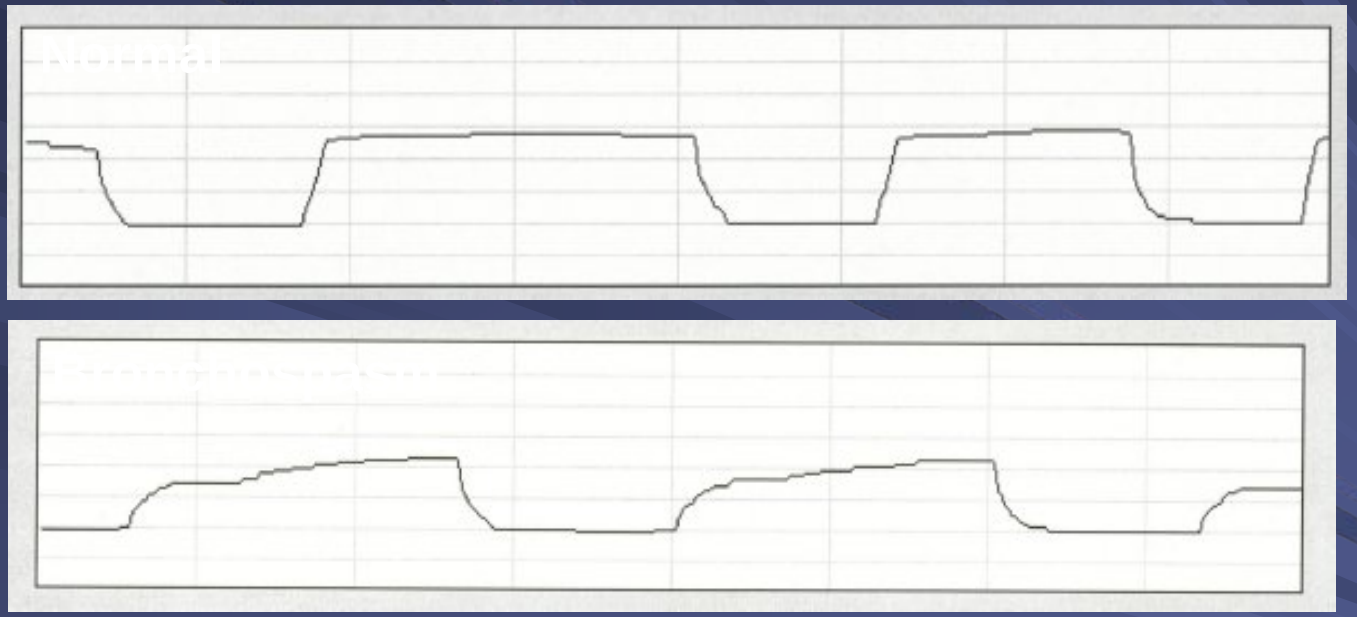
Capnography in Bronchospastic Diseases

- 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 CO_2 seen with increasing bronchospasm

Source: Krauss B., *et al*. 2003. FEV1 in Restrictive Lung Disease Does Not Predict the Shape of the Capnogram. Oral presentation. Annual Meeting, American Thoracic Society, May, Seattle, WA

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

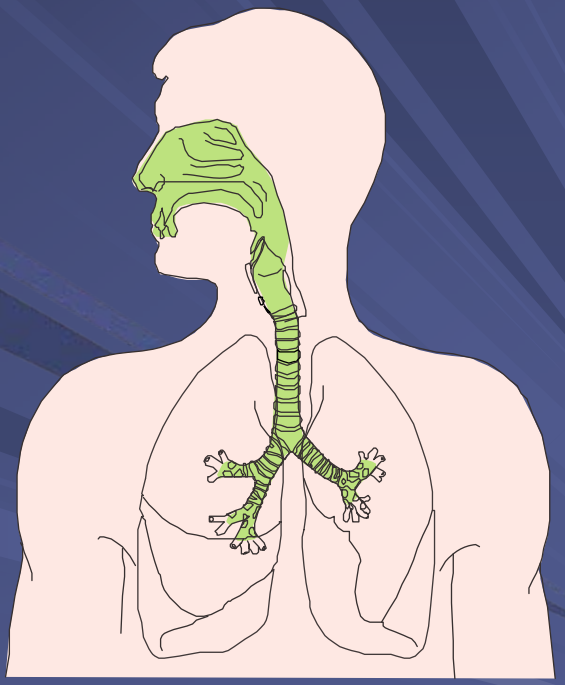
Initial

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

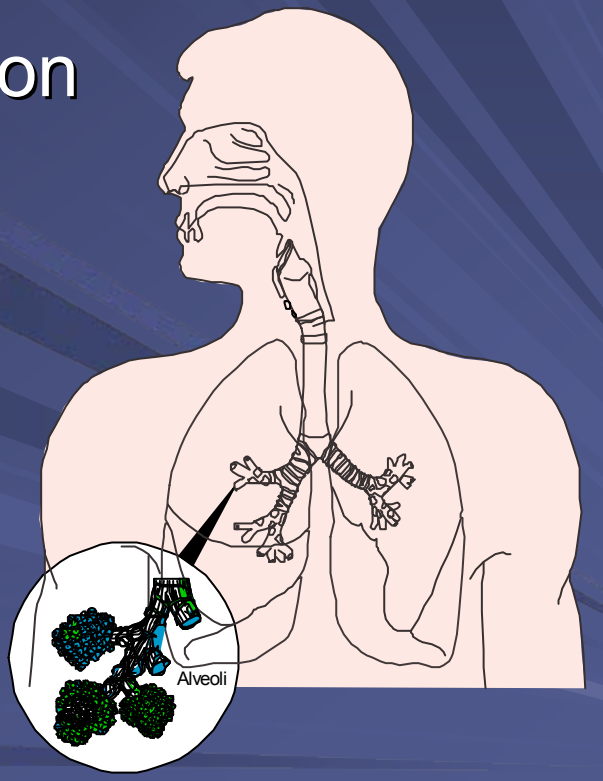


- Hyperplasia: An abnormal increase in the number of cells in an organ or a tissue with consequent enlargement.

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 CO_2 in COPD
  - $PaCO_2$ 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.

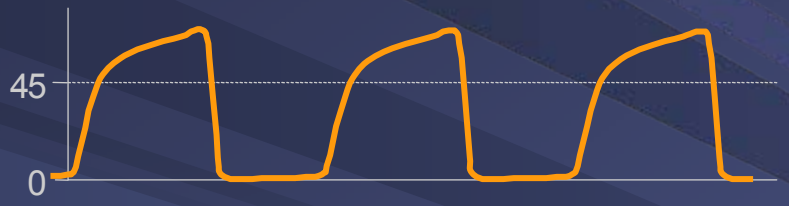
Capnography in Bronchospastic Conditions

COPD Case Scenario

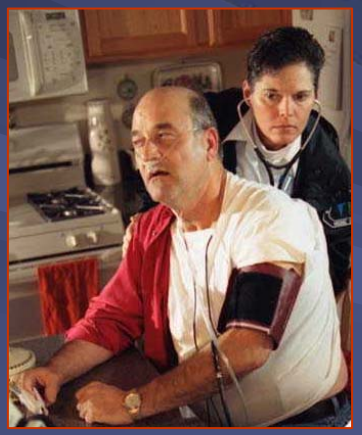
- 72 year old male
- C/O difficulty breathing
- History of CAD, CHF, smoking and COPD
- Productive cough, recent respiratory infection
- Pulse 90, BP 158/82 RR 27

Capnography in Bronchospastic Conditions

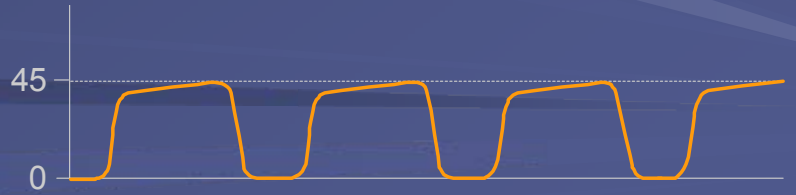
COPD Case Scenario



Initial Capnogram A



Initial Capnogram B



Capnography in CHF

Case Scenario

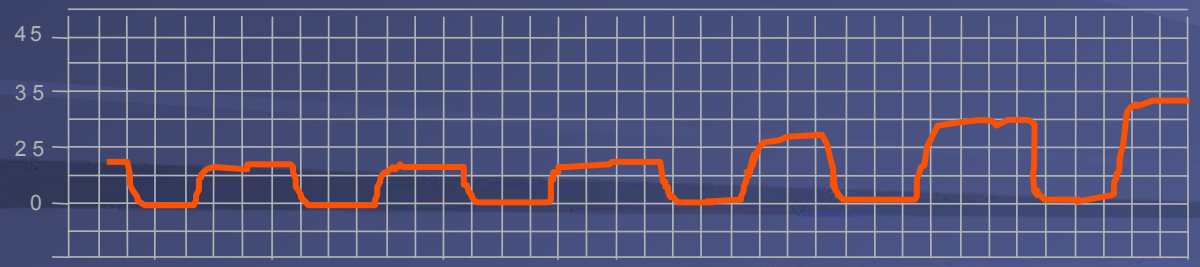
- 88 year old male
- C/O: Short of breath
- H/O: MI X 2, on oxygen at 2 L/m
- Pulse 66, BP 114/76/p, RR 36 labored and shallow, skin cool and diaphoretic, 2+ pedal edema
- Initial SpO_2 69%; $EtCO_2$ 17mmHG

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:

SpO_2 69% ➡ 99%

$EtCO_2$ 17mmHG ➡ 35 mmHG

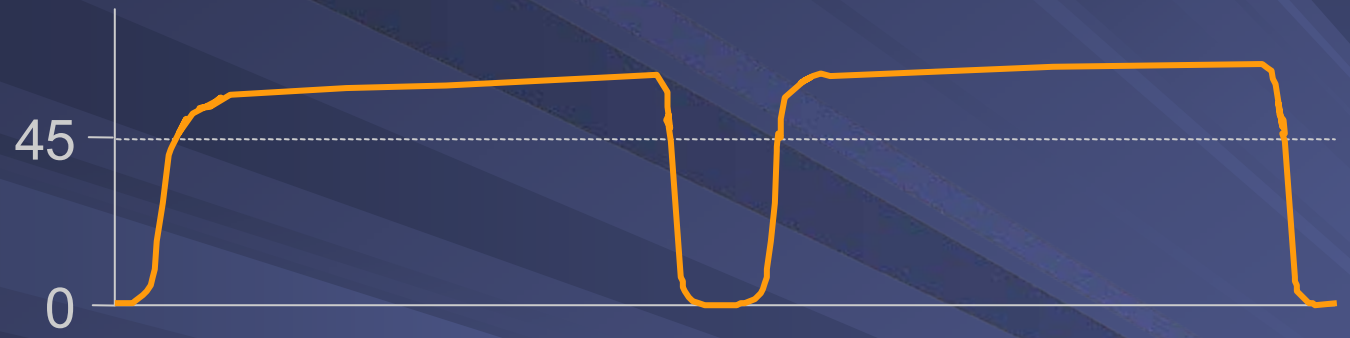


Time condensed to show changes

Capnography in Hypoventilation States

- Altered mental status
  - Sedation
  - Alcohol intoxication
  - Drug Ingestion
  - Stroke
  - CNS infections
  - Head injury
- Abnormal breathing
- CO_2 retention
  - $EtCO_2$ >50mmHg

Capnography in Hypoventilation States



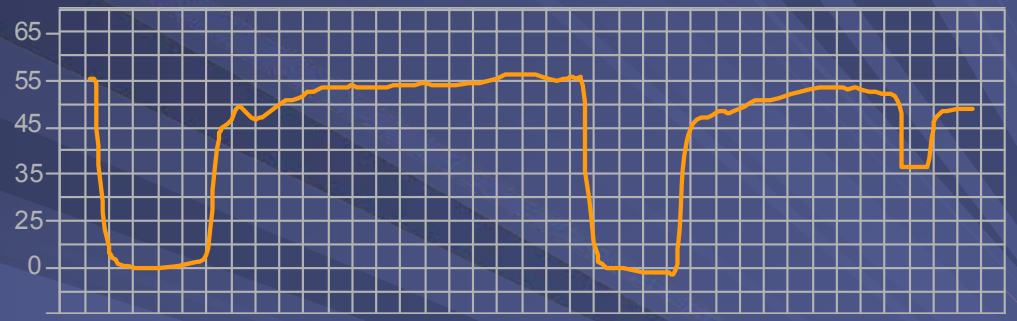
Time condensed; actual rate is slower

- $EtCO_2$ is above 50mmHG
- Box-like waveform shape is unchanged

Capnography in Hypoventilation States
Case Scenario

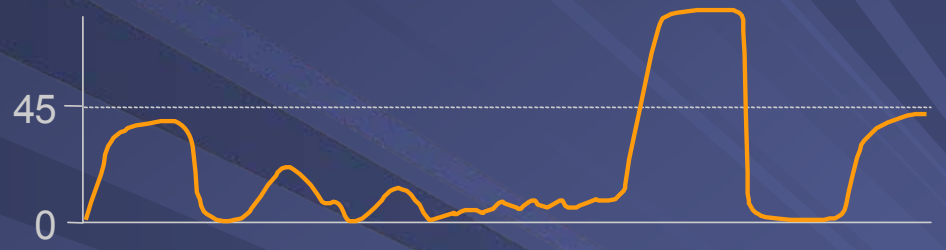
- Observer called 911
- 76 year old male sleeping and unresponsive on sidewalk, “gash on his head”
- Known history of hypertension, EtOH intoxication
- Pulse 100, BP 188/82, RR 10, SpO_2 96% on room air

Capnography in Hypoventilation States
Hypoventilation



Time condensed; actual rate is slower

Capnography in Hypoventilation States
Hypoventilation



Hypoventilation in shallow breathing

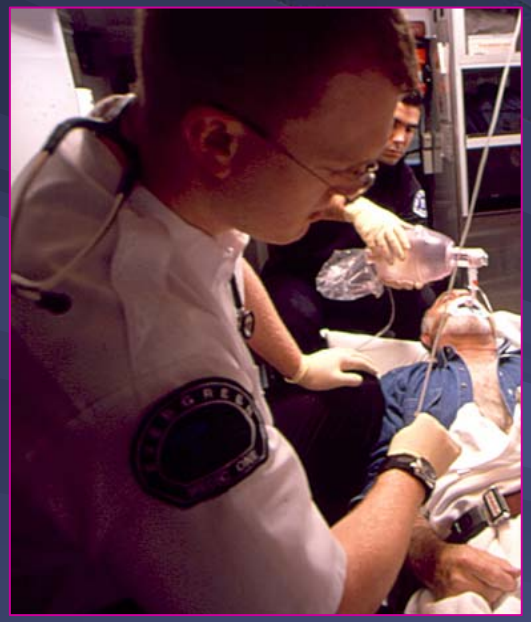
Capnography in Low Perfusion

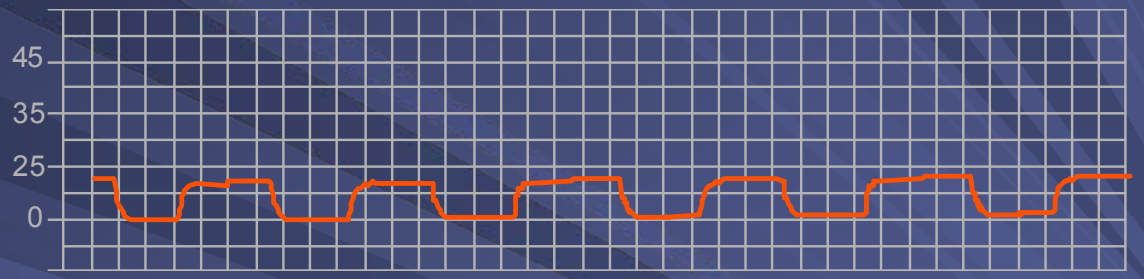
- Capnography reflects changes in
- Perfusion
  - Pulmonary blood flow
  - Systemic perfusion
  - Cardiac output

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





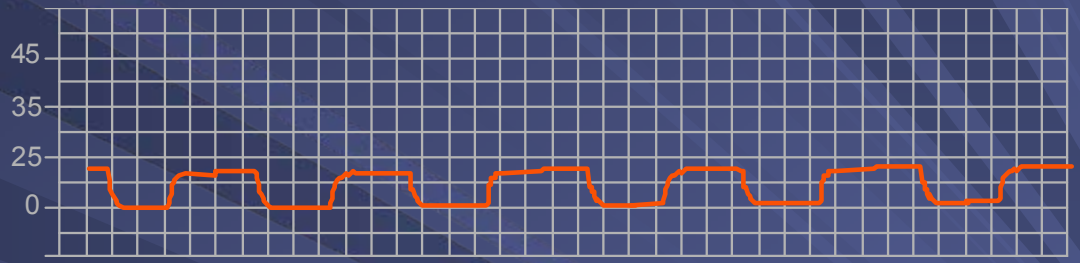
Low $EtCO_2$ seen in low cardiac output

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 HCO_3 and the higher the respiratory rate and lower the $EtCO_2$

Helps is distinguishing DKA vs HHNK

Capnography use with a Head Injured Patient

- Helps to avoid hyperventilation
- Target value of 35mmHG is recommended

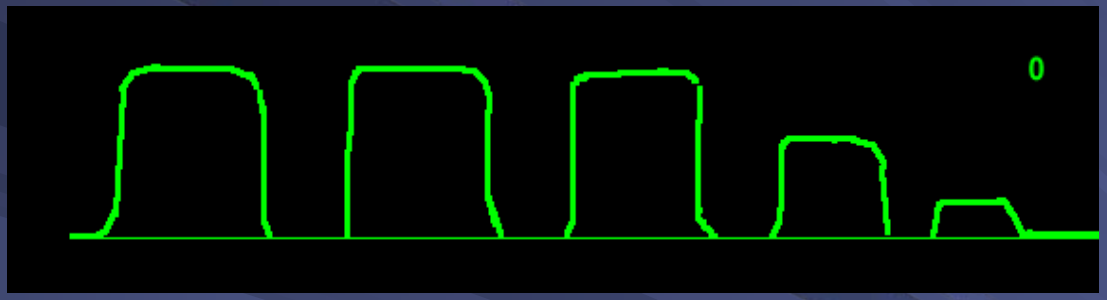
The Non-intubated Patient Summary

- Identify and monitor bronchospasm
  - Asthma
  - COPD
- Assess and monitor
  - Hypoventilation states
  - Hyperventilation
  - Low perfusion
  - Many others now being reported

Capnography Fact or Myth?

Capnography will detect a tracheal intubation, every time.

MYTH!



Carbonated Beverages!

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

Capnography Fact or Myth?

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?
- Its 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

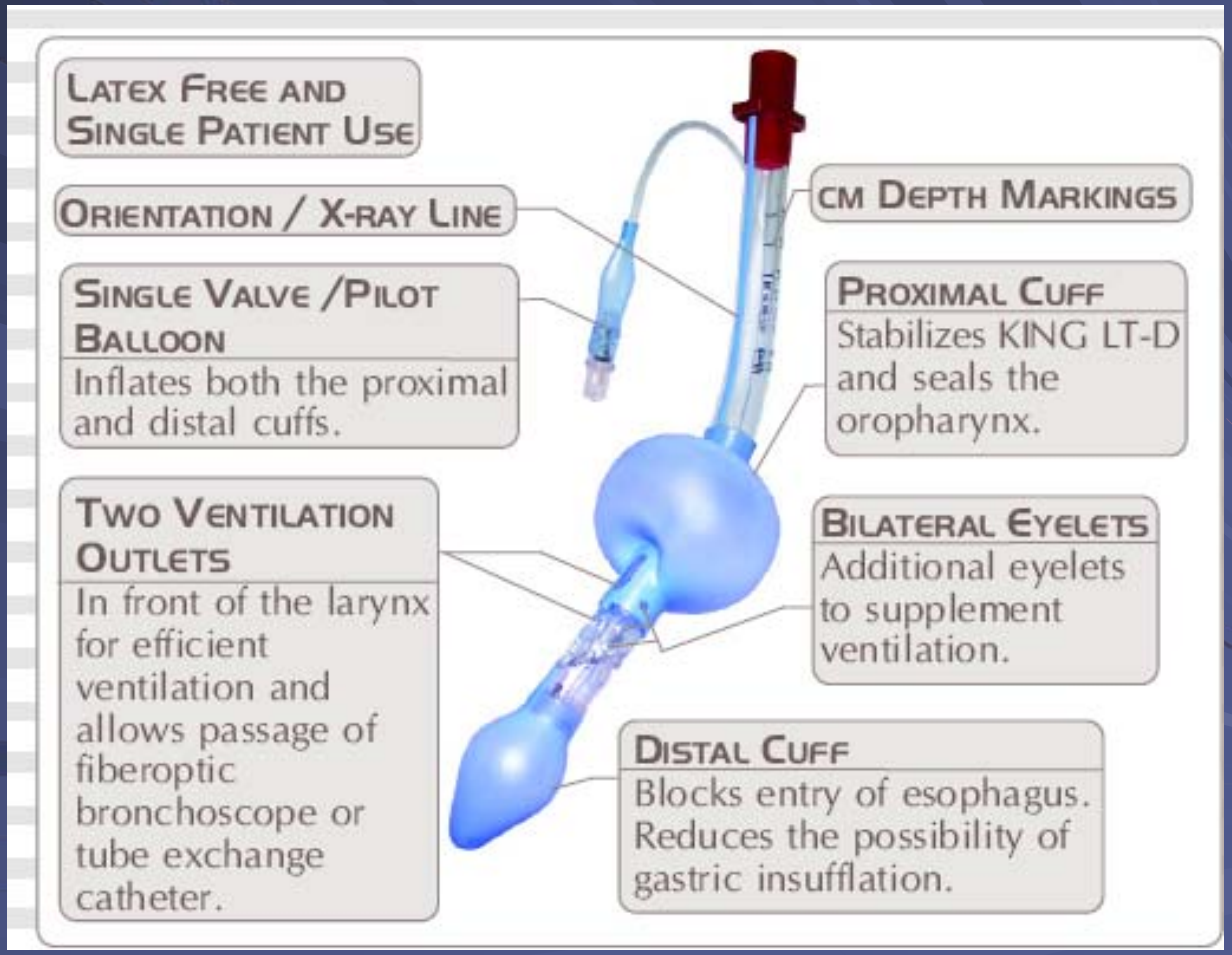
DISPOSABLE!

Review

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.

Review

- 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 a 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 02 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 wave form. Is this reason to remove your airway?

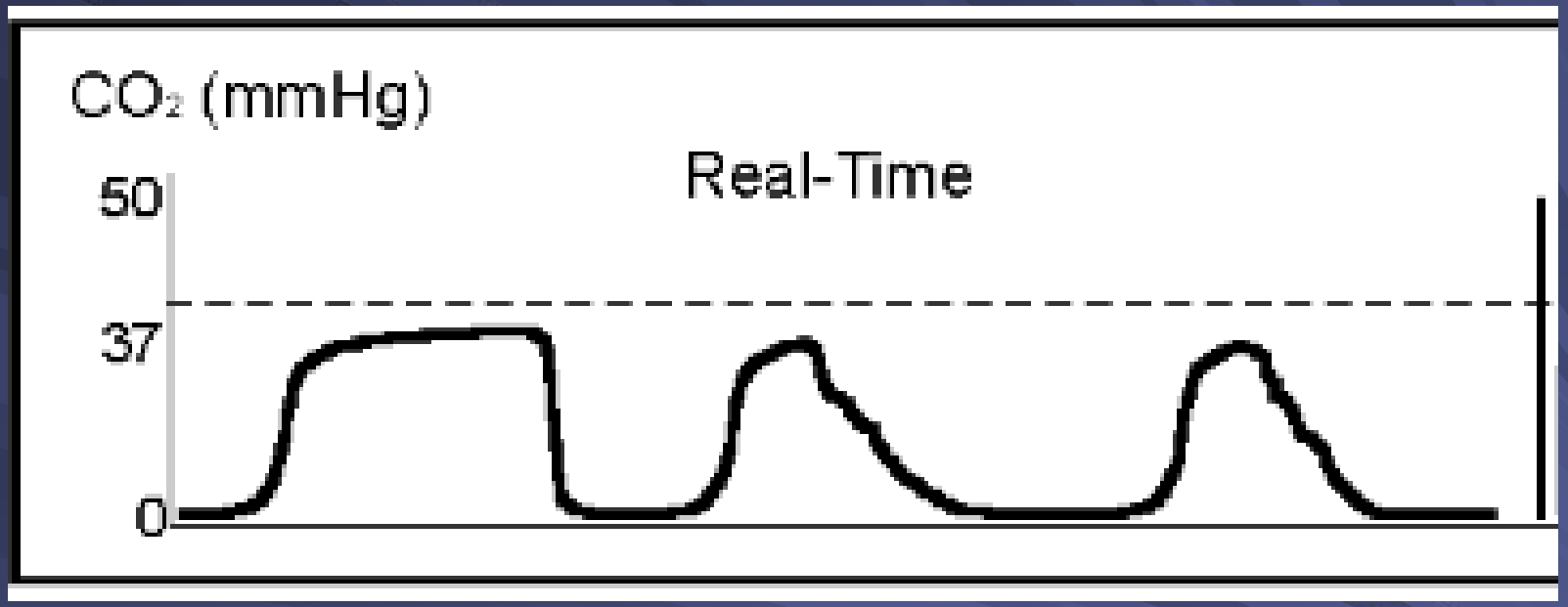
What should you do….

Case Study

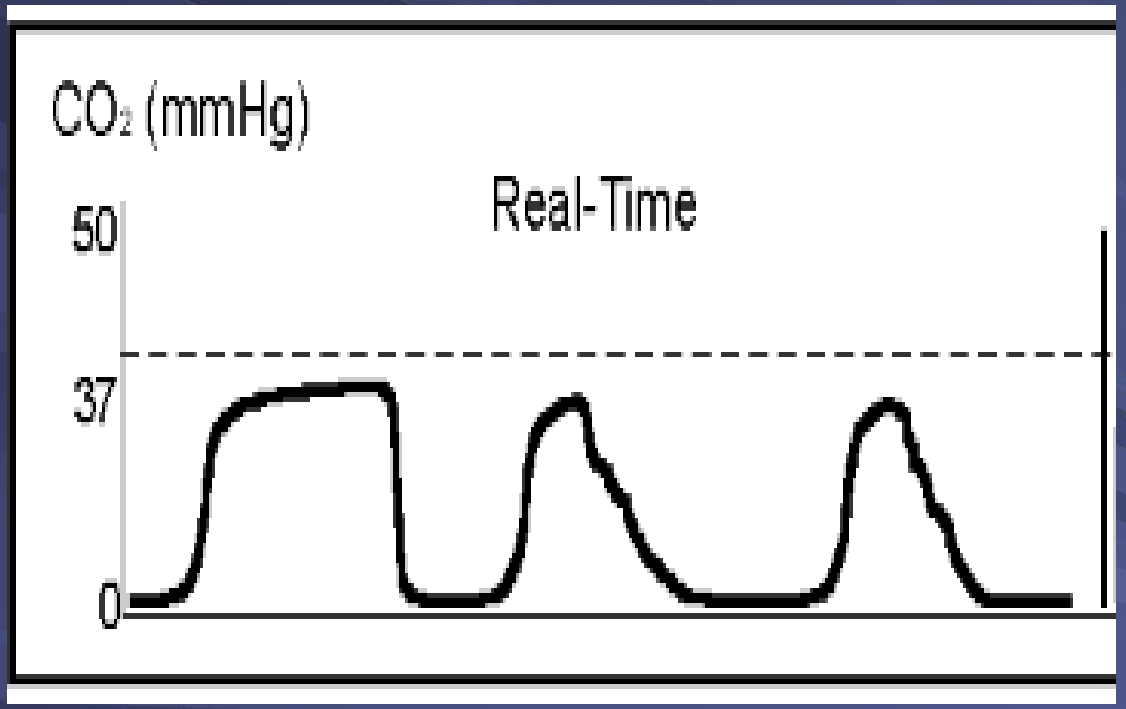
- Listen to lung sounds
- Look for symmetrical chest rise
- Vapor in the tube
- Change in patient color
- Absent abdominal sounds
- Re-visualize placement of tube
- EIDD

Case Study

- 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.


CO_2 (mmHg)
Real-Time
50
37
0

Leaking or inadequate inflation of airway cuff



Is this color good or bad?

Purple is Poop!

Sources

- Paramedic Care: Principles and Practice. Bledsoe, Bryan E. Brady Publishers. 2003.
- Emergency Care. 10th Edition. Limmer, Daniel. Brady Publishers. 2005.
- Capnography for Paramedics. http://emscapnography.blogspot.com
- Capnography in EMS. Kraus, Baruch EdM. JEMS. January 2003.
- Medtronic ERS

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Now let’s play!!

Everyone needs to see how their specific departments EtCo2 monitor works