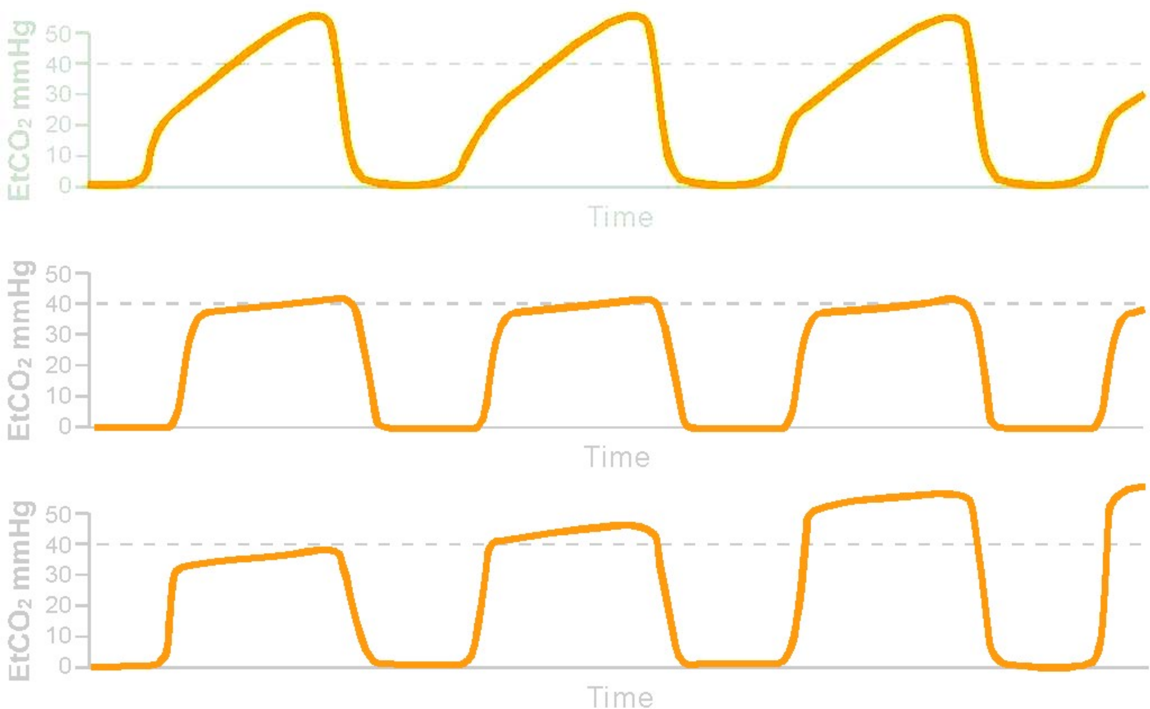
Riding The Waves



The Role of Capnography in EMS

By Bob Page, AAS, NREMT-P, CCEMT-P, I/C

Edutainment

"Riding the Waves"
The Role of Capnography in EMS

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INTRODUCTION

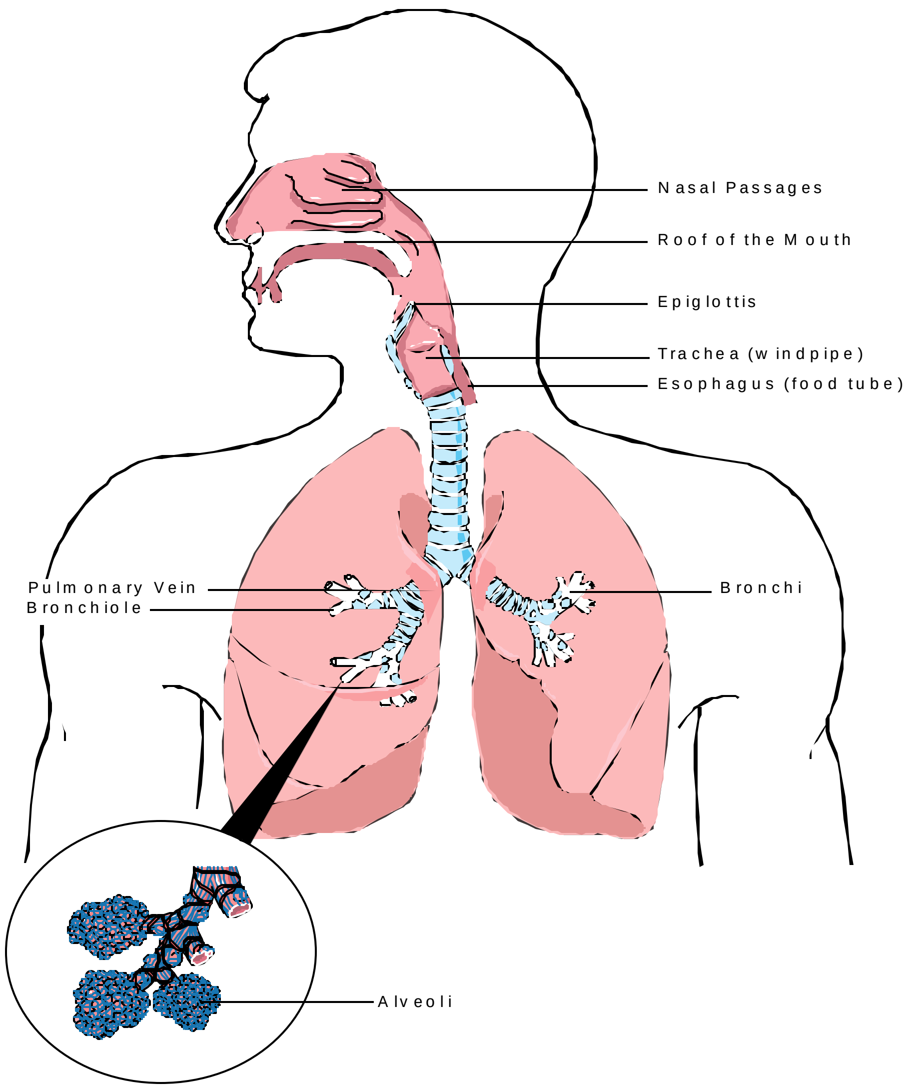
Capnography is a noninvasive method for monitoring the level of carbon dioxide in exhaled breath ($EtCO_2$), to assess a patient's ventilatory status. A true capnogram produces an $EtCO_2$ value as well as a waveform, or capnogram. On Critical Care transports, capnograms are useful for monitoring ventilator status, warning of airway leaks and ventilator circuit disconnections. Capnography is also useful for ensuring proper endotracheal tube placement. Capnography also helps clinicians diagnose specific medical conditions, make treatment decisions, and assess efficacy of code efforts and predict outcome.

Capnography offers numerous clinical uses, but technical limitations have prevented EMS personnel from embracing its use outside the operating room. Today, technological advances have made it possible for these devices to be used in the demanding setting of the prehospital environment.

OBJECTIVES for the Session:
By the end of this session, you will be able to:

- Describe the structure and function of the upper and lower airways.
- Describe the mechanics and science of ventilation and respiration.
- Describe the basic physiology of perfusion.
- Describe the relationship between ventilation and perfusion.
- Describe the principles behind CO_2 measurement.
- Describe the various methods of $EtCO_2$ measurement including quantitative and qualitative capnometry and capnography.
- Describe the technology of $EtCO_2$ measurement including mainstream, sidestream and microstream sampling.
- Identify the components of a normal capnogram waveform.
- Identify abnormal capnogram waveforms as related to various airway, breathing and circulation problems.
- Discuss the various clinical applications of capnography in the field.
- Given various cases, discuss the role of capnography in identifying the problem and in the management of the patient.

MODULE ONE:
REVIEW OF AIRWAY ANATOMY AND PHYSIOLOGY



Two divisions to the airway:

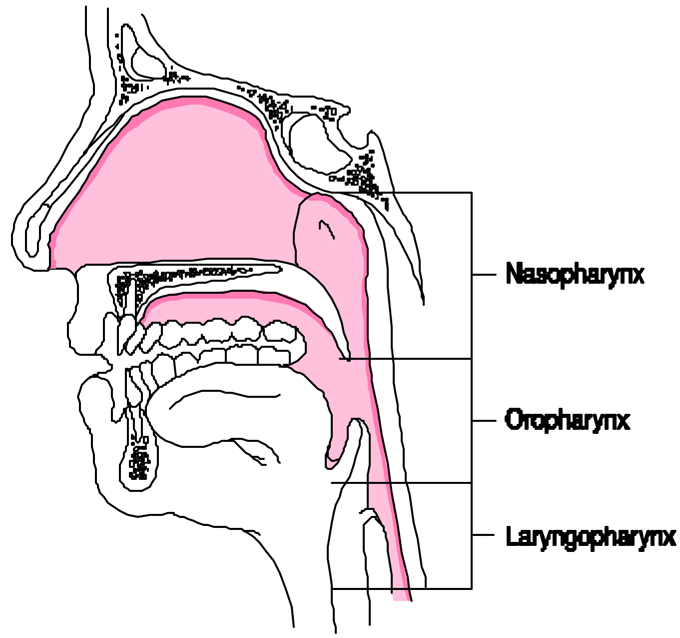
1. Upper Airway

2. Lower Airway

Airway Anatomy Review

- Upper Airway

  Nasopharynx



  Oropharnyx

  Palates

    Hard and soft

  Larynx

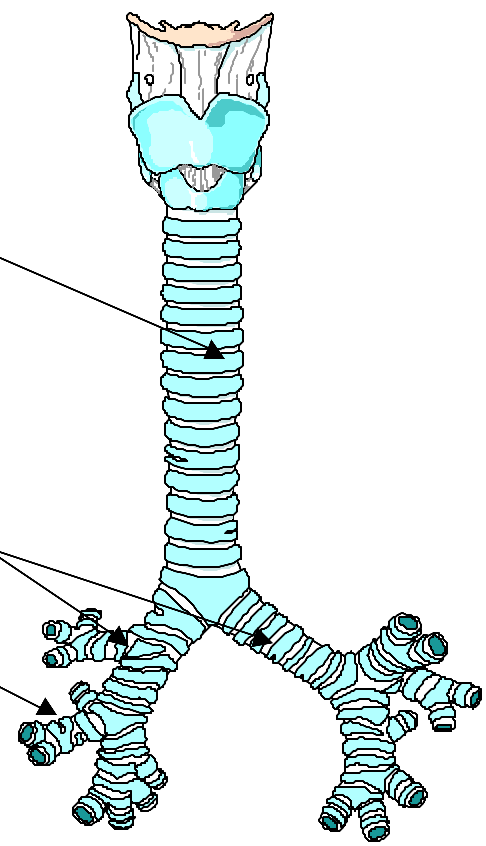
    Epiglottis

    Vocal cords

Upper Airway Physiology: PEEP or Positive End Expiratory Pressure can be defined as the pressure against which exhalation occurs. The purpose of PEEP is to prevent alveolar collapse. The structure and path way of the upper airways provide for a natural or "physiological PEEP."

The primary roles of the upper airway are to _____________, _______________, and ________________ the air entering the lungs.

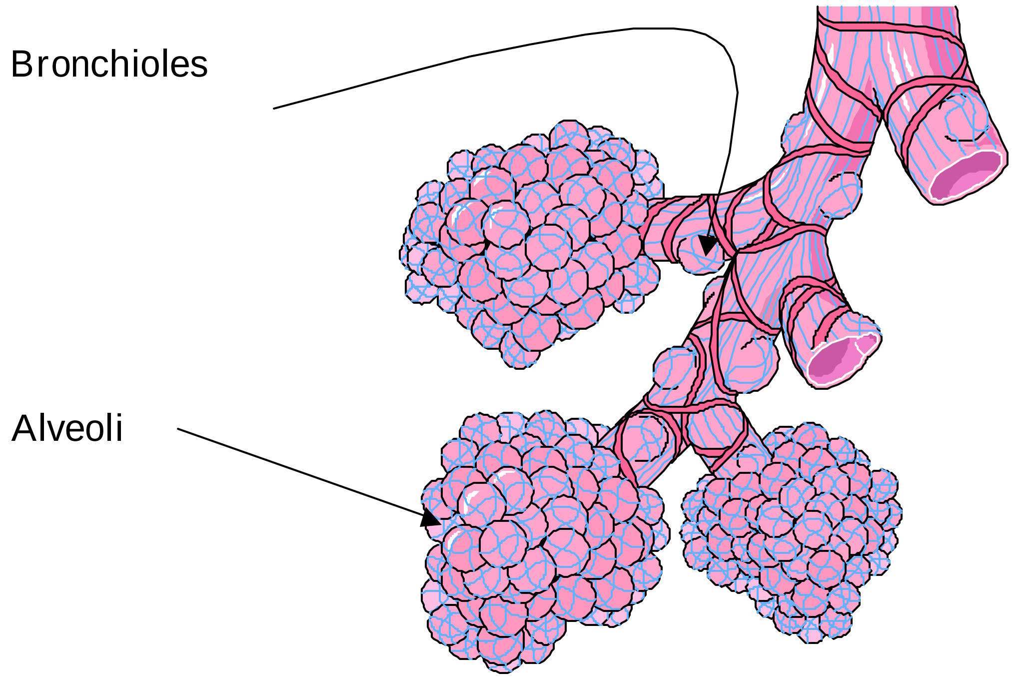
- Lower Airway



Dead Space Air

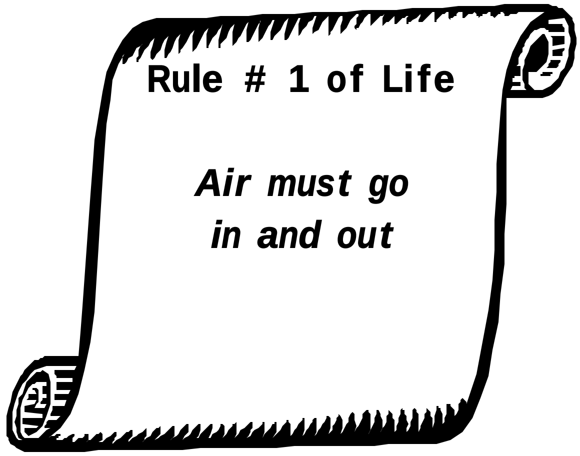
The lower airway is comprised of the trachea, bronchi and then 25 divisions of the bronchial tree terminating at the respiratory bronchioles and the alveoli.

The areas from the bronchioles to the nose comprise the total dead space air. This is air that is not exchanged.



The alveoli are tiny air sacs where gas exchange occurs. O_2 and CO_2 are exchanges at the capillary-alveolar membrane.

THE PHYSIOLOGY OF VENTILATION



- Function of ventilation***:***

  ***Ventilation** is the movement of air.*

  - Designed to eliminate CO_2 and take in O_2

How air moves (and it MUST move)

- Chemoreceptors in the medulla sense elevated levels of CO_2 or lowered pH, triggering ventilation. *Known as hypercarbic drive*.
- Diaphragm contracts and moves downward.
- Intercostal muscles spread chest wall out increasing the volume inside the chest.
- Differences in pressure inside the chest and outside causes air to move into the lungs.
- Hypoxic drive (low O_2 levels) is secondary drive.

VOLUME CAPACITIES

- **Tidal Volume (Vt)**: The amount of air moved in one breath
  - Typically 500 cc in an adult at rest

- **Anatomical Dead Space (Vd)**: Air not available for gas exchange
  - About 150 cc

- **Alveolar volume (Va)**; Air that is available for gas exchange
  - About 350 cc (Vt – Vd = Va)
  - Anything that affects the tidal volume *only* affects the alveolar volume.

Factors affecting the tidal volume

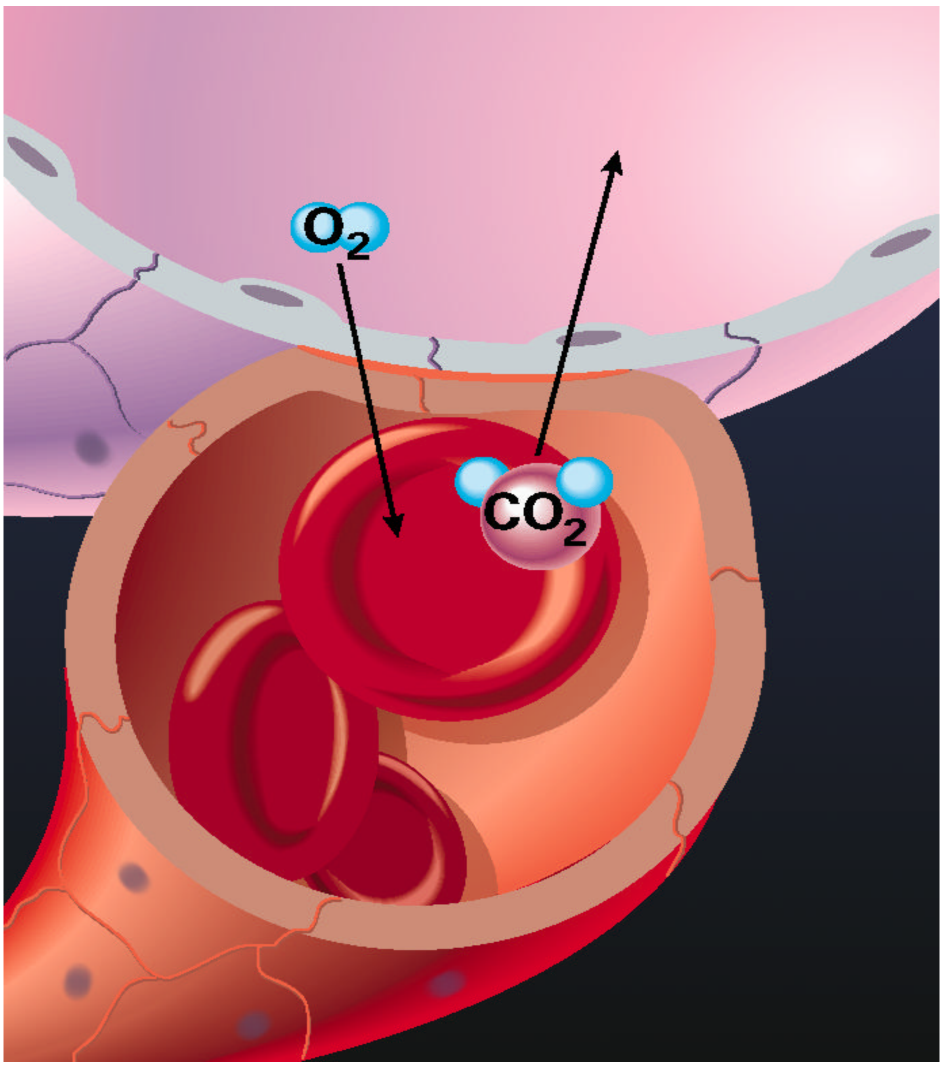
- Hyperventilation
  - Fast breathing (tachypnea) doesn't necessarily increase tidal volume
  - Anxiety, head injuries, diabetic emergencies, PE, AMI, and others

- Hypoventilation
  - Slow breathing (bradypnea) does not necessarily decrease tidal volume.
  - Causes include CNS disorders, narcotic use and others.

Street Wisdom: An increase or decrease in tidal volume is at the expense or benefit of alveolar air.

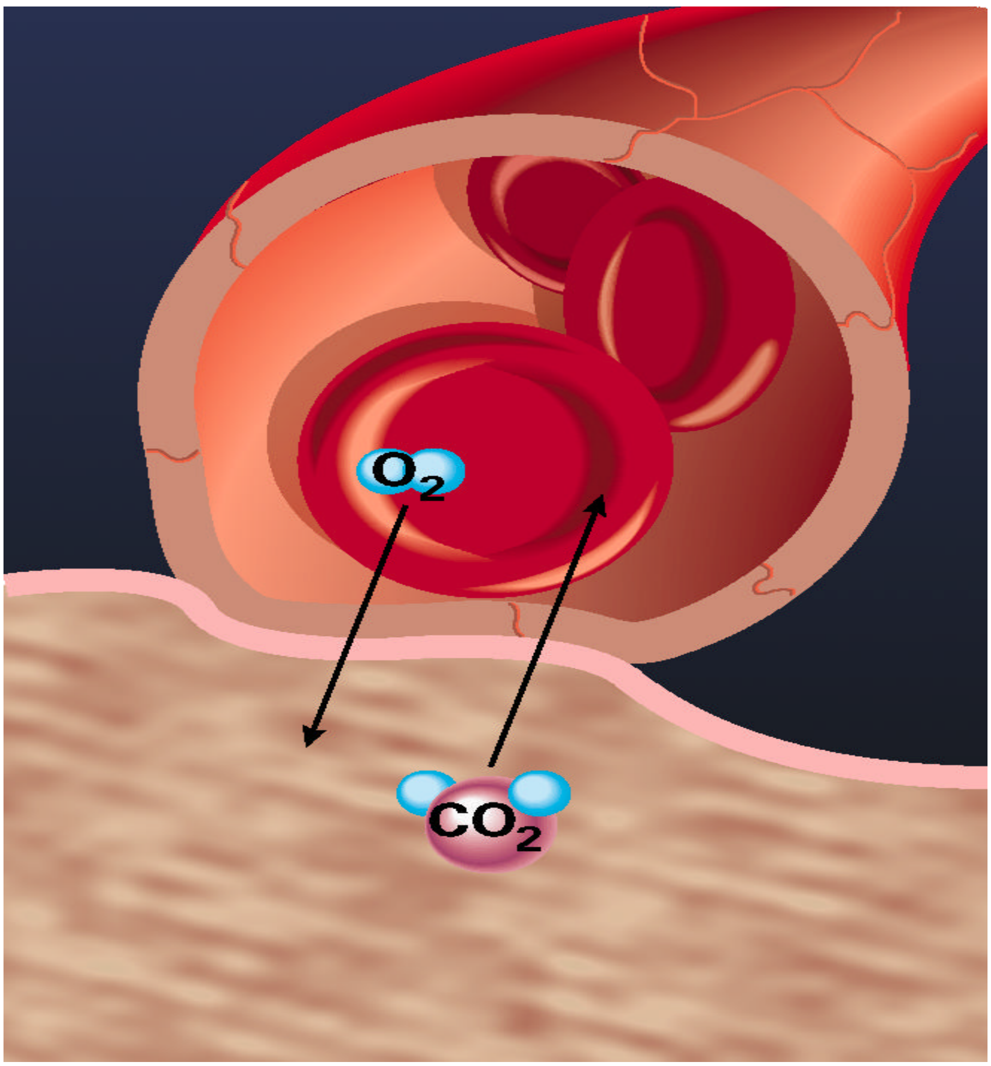
Respiration is the exchange of gases

Alveolar respiration occurs between the _______ and _________ in the lungs.

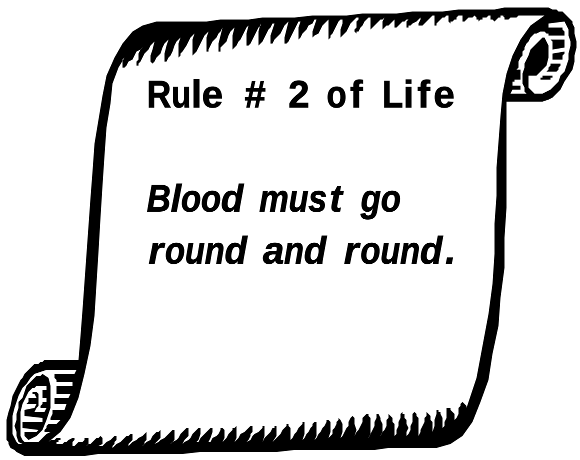


Cellular respiration occurs between the _____ in the body and the ______________.

When there is a difference in partial pressure between the two containers, gas will move from the area of greater concentrations to the area of lower concentration. a.k.a. diffusion

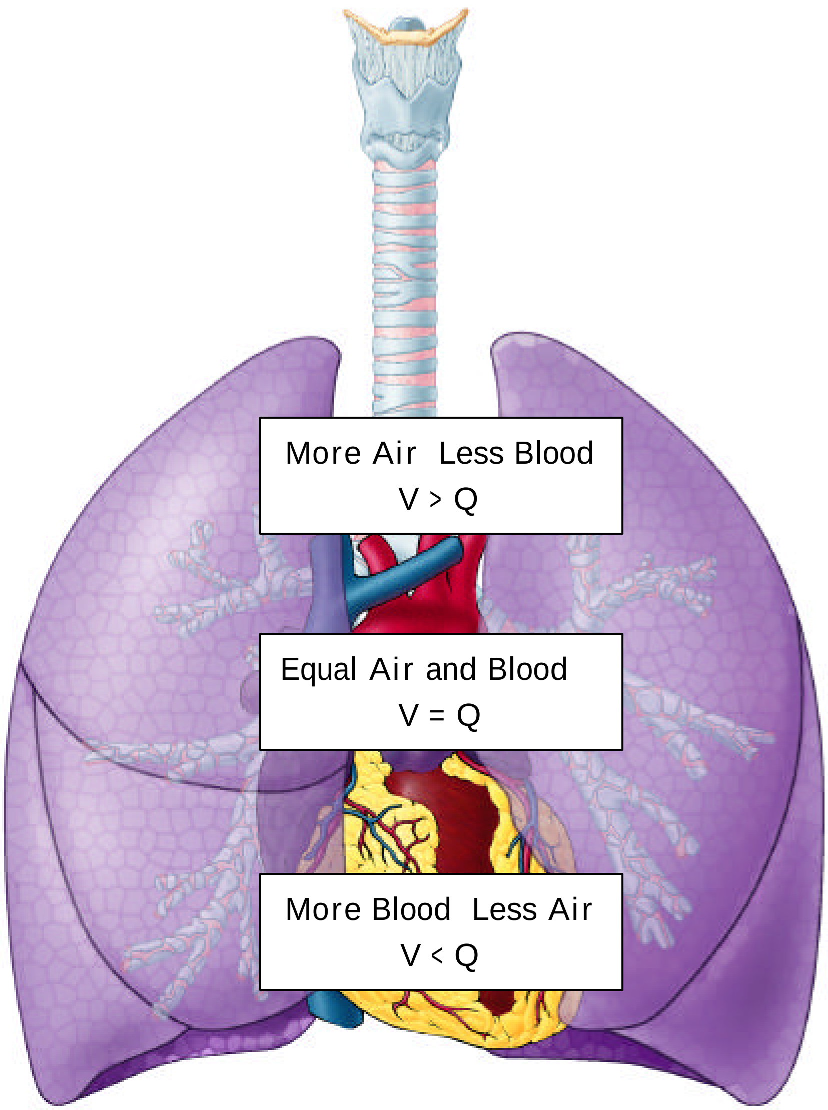


THE PHYSIOLOGY OF PERFUSION



- **Fick principle**: Oxygen Transport
- In order from adequate cellular perfusion to occur, the following must be present:
  - Adequate number of Red Blood Cells (RBC's)
    - Hemoglobin on the RBC's carry the oxygen molecules
  - Adequate O_2
    - Patient must have adequate O_2 coming in. See Rule of Life #1
  - RBC's must be able to offload and take on O_2
    - Some conditions such as carbon monoxide poisoning and cyanide poisoning affect the RBC's ability to bind and release O_2 molecules.
  - Adequate blood pressure to push cells

PHYSIOLOGIC BALANCE



- **Pathological Conditions**
  - Normal ventilation, poor perfusion: P.E., Arrest
  - Abnormal ventilation, good perfusion: obstruction, O.P.D., drug OD
  - Bad ventilation and perfusion: Arrest
  - Bad exchange area: CHF

Critical Thinking Cases – Designed to illustrate the pathophysiology

- Normal ventilation/normal perfusion
- Normal ventilation/compromised perfusion
- Compromised ventilation/normal perfusion
- Compromised ventilation and perfusion

1. 26 year-old female patient took an overdose of Valium. She is UNCONSCIOUS. V/S are 110/70, pulse is 64, RR is 12 and very shallow, skin is warm and dry.

2. 65 year-old male patient complaining of a sudden onset of right sided chest pain and dyspnea. He has no medical history except for a hip replacement surgery about 3 weeks ago. His lung sounds are clear. VS are B/P 140/78, pulse is 110, and RR is about 20 and normal depth.

3. 80 year-old man complains of a sudden onset of severe headache. He has flushed skin, and has obvious facial droop to the left side. He has a history of high blood pressure. V/S are B/P 180/110, pulse is 100 and RR is 16 and normal depth.

4. 37 year-old female that was involved in a head on collision. Windshield is starred and the steering wheel is broke. Bruising and crepitus found over the left chest. Pt is unconscious, difficult to bag with absent lungs sounds on the left side. Blood pressure is 60/40; pulse is 130 and weak at the carotid. There is obvious JVD. Skin is cool and clammy.

MODULE TWO:
TECHNOLOGY OF CAPNOGRAPHY

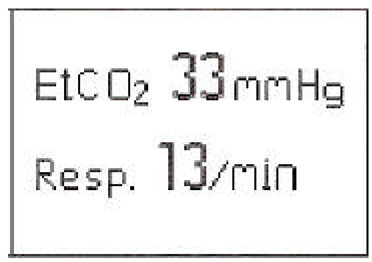
The Role of CO_2

- CO_2 is the "Gas of Life"
- Produced as a normal by-product of metabolism.

Measurement of $EtCO_2$ (Capnometry)

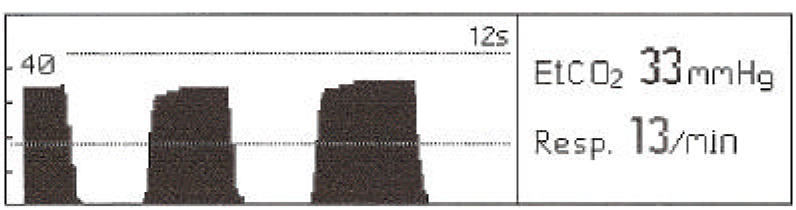
- Qualitative
  - Color change assay
    - (CO_2 turns the sensor from purple to yellow)

- Quantitative
  - Gives you a value ($EtCO_2$)
  - Respiratory Rate



Waveform Capnography

- Features quantitative value and waveform
- Capnography includes Capnometry



Street Wisdom: ***"End Tidal CO_2 reading without a waveform is like a heart rate without an ECG recording."***

- **Infrared (IR) Spectroscopy**:
  - Most often used
  - Infrared light is used to expose the sample
  - IR sensors detect the absorbed light and calculate a value
  - Broad spectrum IR beams can be absorbed N_20 and High O_2 levels

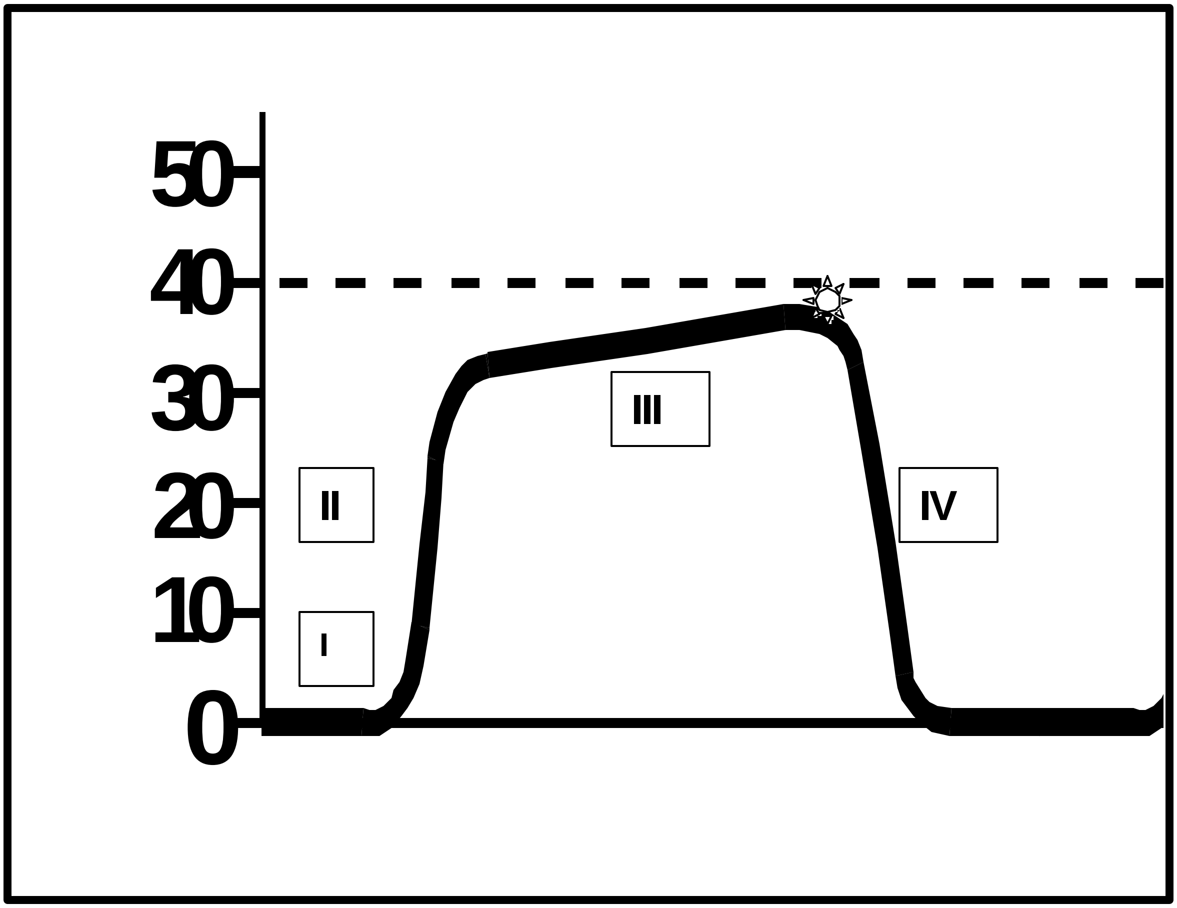
- **Side stream sampling**
  - "First generation devices"
  - Draws large sample into machine from the line
  - Can be used on intubated and non-intubated patients with a nasal cannula attachment

  - "Second generation devices"
  - Airway mounted sensors
  - Generally for intubated patients

- **Microstreamã Technology**
  - Position independent adaptors
  - Moisture, secretion, and contaminant handling in three ways
    - Samples taken from center of line, and in $1/20^{th}$ the volume
    - Vapor permeable tubing
    - Sub micron-multi-surface filters
  - Expensive parts are protected
  - Microbeam IR sensor is CO_2 specific
  - Suitable for adult and pediatric environments.

MODULE THREE:
CLINICAL APPLICATIONS OF CAPNOGRAPHY

- **THE NORMAL CAPNOGRAM**



Phase I: Respiratory Baseline

Phase II: Expiratory Upstroke

Phase III: Expiratory Plateau

ETCO_2: Peak EtCO_2 level ☼

Phase IV: Inspiratory Downstroke

Systematic Approach to Waveform Interpretation

1. Is CO_2 present? (waveform present)
2. Look at the respiratory baseline. Is there rebreathing?
3. Expiratory Upstroke: Steep, sloping, or prolonged?
4. Expiratory (alveolar) Plateau: Flat, prolonged, notched, or sloping?
5. Inspiratory Downstroke: Sleep, sloping, or prolonged?
6. Read the $EtCO_2$
7. If ABG is available, compare the $EtCO_2$ with $PACO_2$
   a. If they are within 5mm/hg of each other then the problem is ventilatory and not perfusion.
   b. $EtCO_2$ can be used in many cases in lieu of ABG's

The ABC's of Waveform Interpretation!

A – Airway: Look for signs of obstructed airway (steep, upsloping expiratory plateau)

B – Breathing: Look at $EtCO_2$ reading. Look for waveforms, and elevated respiratory baseline.

C – Circulation: Look at trends, long and short term for increases or decreases in $EtCO_2$ readings

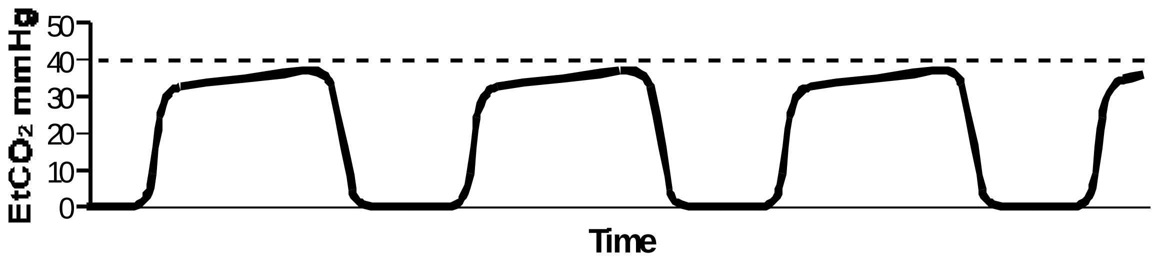
Street wisdom: ***A patient complains of having difficulty breathing. The pulse oximeter shows 98% on 15 lpm O_2. As you attempt to listen to lung sounds, they are hard to make out in the back of the ambulance. What benefit, if any could capnography make in the diagnosis and management of this patient?***

What is the difference between pulse oximetry and capnography?

SpO_2 = Pulse oximetry – measures oxygenation

$EtCO_2$ = Capnography – measures ventilation

NORMAL CAPNOGRAPHY



This is a normal capnogram that has all of the phases that are easily appreciated. Note the gradual upslope and alveolar "Plateau"

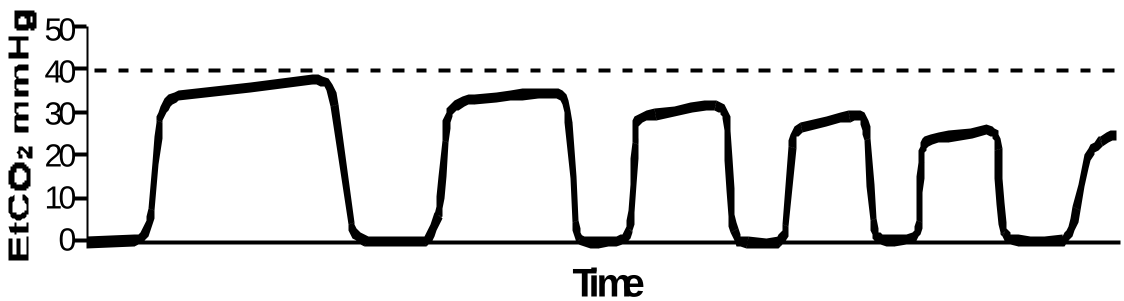
Point for thought:

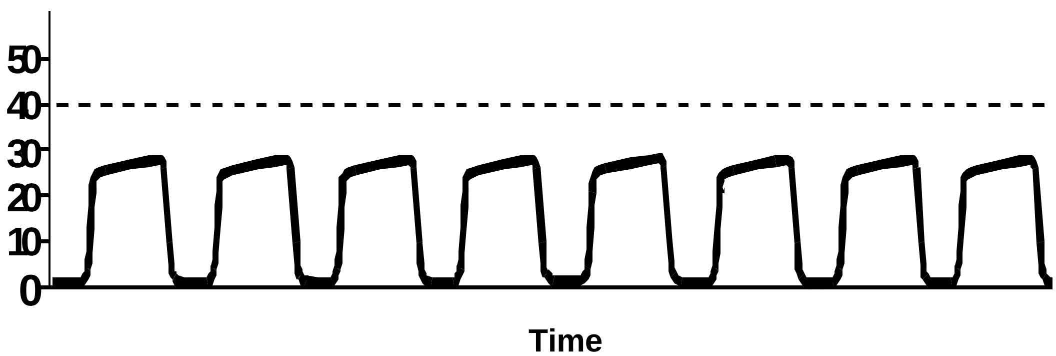
List the things a normal capnogram tells you and the things that it does not tell you.

ABNORMAL CAPNOGRAPHY

- **Hyperventilation**

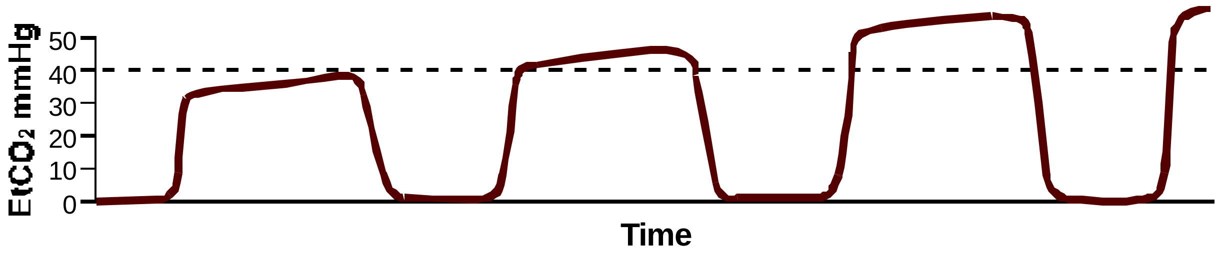
This capnogram starts slow and has an $EtCO_2$ reading that is normal. Notice as the rate gets faster, the waveform gets narrower and there is a steady decrease in the $EtCO_2$ to below 30mm/hg. Causes of this type of waveform include:





- Hyperventilation syndrome
- Overzealous bagging
- Pulmonary embolism

- **Hypoventilation**

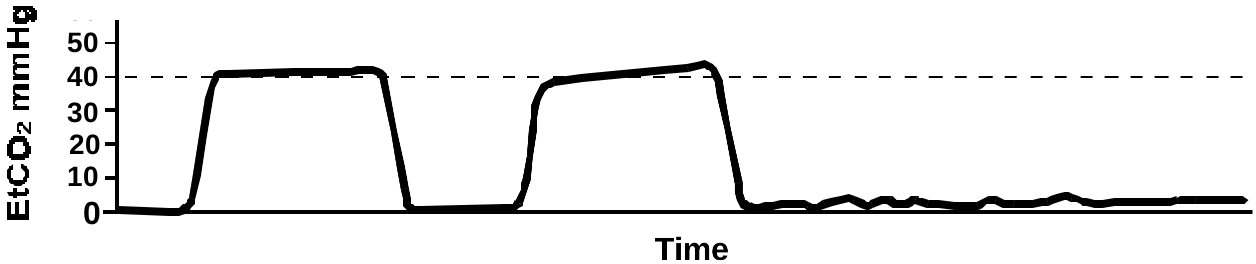


In this capnogram, there is a gradual increase in the EtCO$_2$. Obstruction is not apparent. Causes of this may include:

Respiratory depression for any reason

- Narcotic overdose
- CNS dysfunction
- Heavy sedation

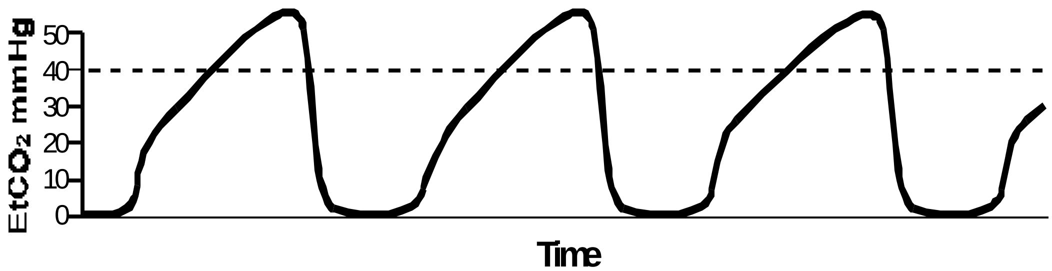
- **Apnea**



This capnogram shows a complete loss of waveform indicating no CO_2 present. Capnography allows for instantaneous recognition of this potentially fatal condition. Since this occurred suddenly, consider the following causes:

- Dislodged ET Tube
- Total obstruction of ET Tube
- Respiratory arrest in the non-intubated patient
- Equipment malfunction (If the patient is still breathing) Check all connections and sampling chambers

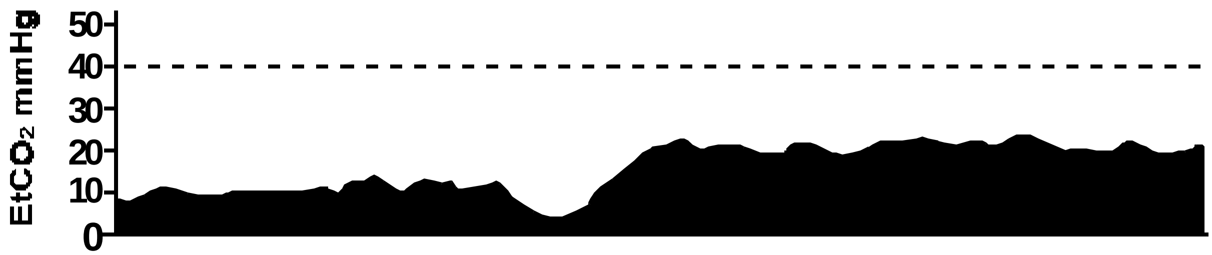
Loss of Alveolar Plateau



This capnogram displays an abnormal loss of alveolar plateau meaning incomplete or obstructed exhalation. Note the "Shark's fin" pattern. This pattern is found in the following Bronchoconstriction

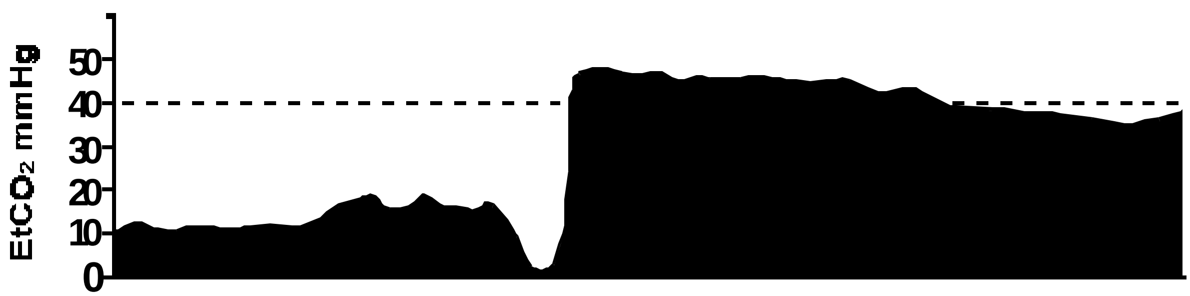
- Asthma
- COPD
- Incomplete airway obstruction
- Upper airway
    - Tube kinked or obstructed by mucous

- **Poor perfusion (cardiac arrest)**



Time: 30 minute trend

The capnogram can indicate perfusion during CPR and effectiveness of resuscitation efforts. Note the trough in the center of the capnogram. During this time, there was a change in personnel doing CPR. The fatigue of the first rescuer was demonstrated when the second rescuer took over compressions.



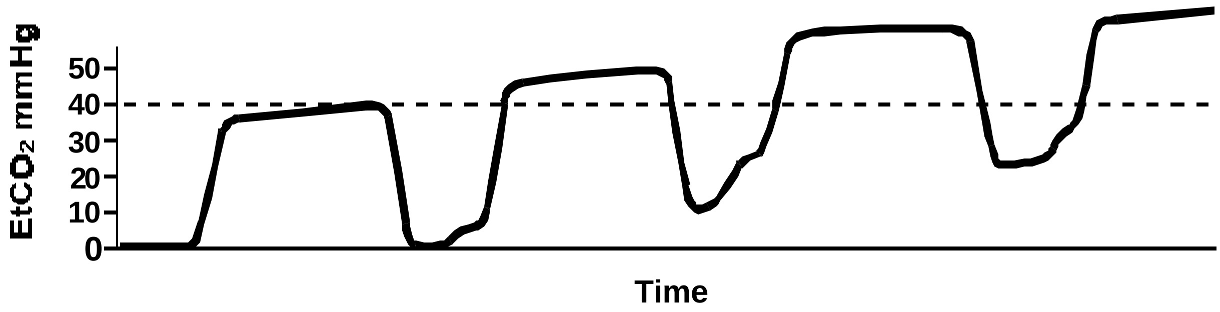
Time: trend 30 minutes

This patient was defibrillated successfully with a return of spontaneous pulse.

Notice the dramatic change in the $EtCO_2$ when pulses were restored.

Studies have shown that consistently low readings (less than 10mm) during resuscitation reflect a poor outcome and futile resuscitation.

- **Elevated Baseline**



This capnogram demonstrates an elevation to the baseline. This indicates incomplete inhalation and or exhalation. CO_2 does not get completely washed out on inhalation. Possible causes for this include:

- Air trapping (as in asthma or COPD)
- CO_2 rebreathing (ventilator circuit problem)

What other condition(s) might produce this type of waveform?

Field Clinical Applications for Capnography

- Closed Head Injury
- Increased intracranial pressure (ICP) tied to increased blood flow following injury (swelling)
- Hypoxic cells produce CO_2 in the brain
- CO_2 causes vasodilation and more blood fills the cranium, increasing pressure.
- Hyperventilation is no longer recommended
- Ventilation should be geared towards controlling CO_2 levels but not overdoing it.
- Obstructive Pulmonary Diseases
  - Asthma, COPD
  - Waveform can indicate bronchoconstriction where wheezes might not have been heard
  - Monitor the effectiveness of bronchodilator therapy
- Tube Conformation
  - Capnography will detect the presence of CO_2 in expired air conforming ETT placement
  - No longer acceptable to use only lungs sounds to confirm
  - A dislodged tube will be detected immediately with capnography
  - Kinking or clotting tubes can also be detected
  - In cases of ventilator use, capnography can detect problems in rebreathing.
- Perfusion
  - Capnography can be set up to trend $EtCO_2$ to detect the presence or absence of perfusion
  - Is a proven predictor of those who do not survive resuscitation
  - When an ABG is available, can detect ventilatory or perfusion problems

MODULE FOUR:
CASE SIMULATIONS AND EVALUATION

CASE # 1

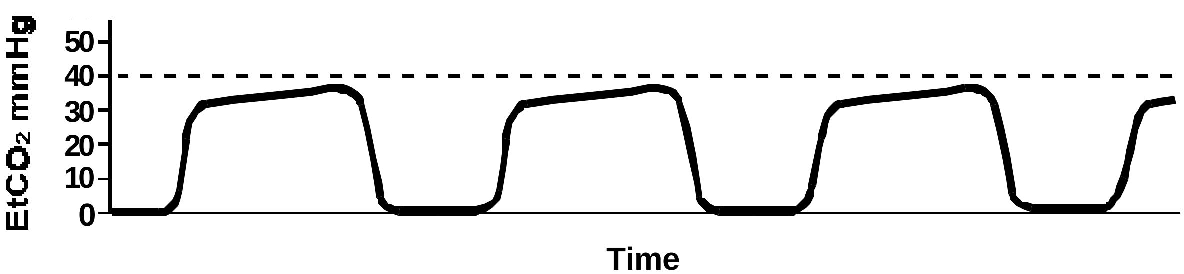
Presentation

Patient is a 65 year old male complaining of crushing substernal chest pain. He rates the pain as a 10 on a scale of one to ten. He denies and shortness of breath or any other complaints. He has a history of cardiac disease and asthma.

Clinical Situation

V/S: 130/80, Pulse is 100, RR is about 20
SpO_2 is 96%, $EtCO_2$ is 40

Cardiac Monitor shows Sinus Tachycardia
His capnogram is as follows.



Questions:
Is the $EtCO_2$ within normal limits?

Is the waveform normal or abnormal? Why or Why Not?

What can you deduce about the ventilation status?
A
B
C

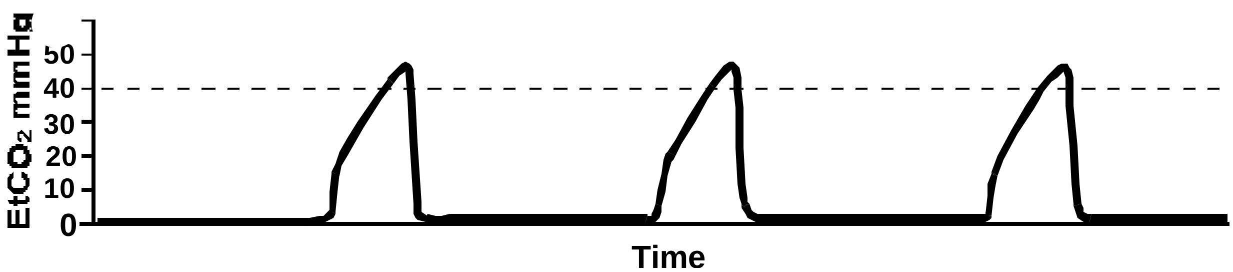
CASE #2

Presentation

Patient is a 25-year-old male patient with a history of asthma. He has been compliant with his medications until he ran out of albuterol. Today, while at a basketball game, he suddenly gets short of breath. He does not have his albuterol inhaler with him. He presents sitting in the bleachers, in minor respiratory distress. It is noisy and hard to hear lung sounds.

Clinical Situation

B/P 120/76
Pulse 100
RR – 14
SpO_2 94
$EtCO_2$ is 50



Questions:

Is the $EtCO_2$ within normal limits?

Is the waveform normal or abnormal? Why or Why Not?

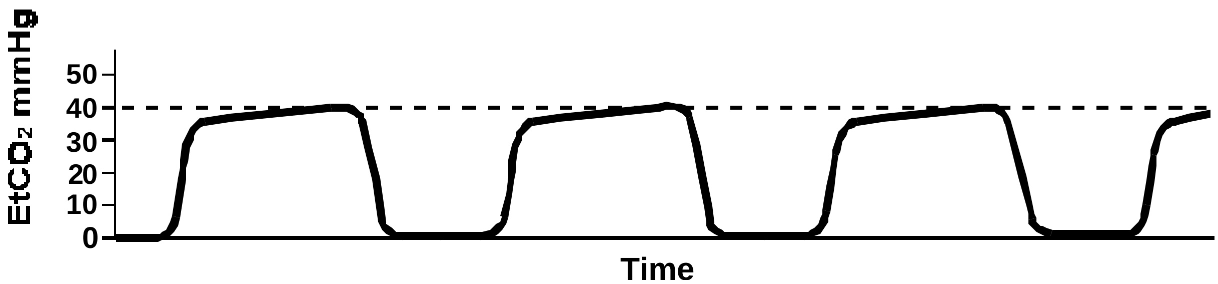
What can you deduce about the ventilation status?
A
B
C

CASE #3

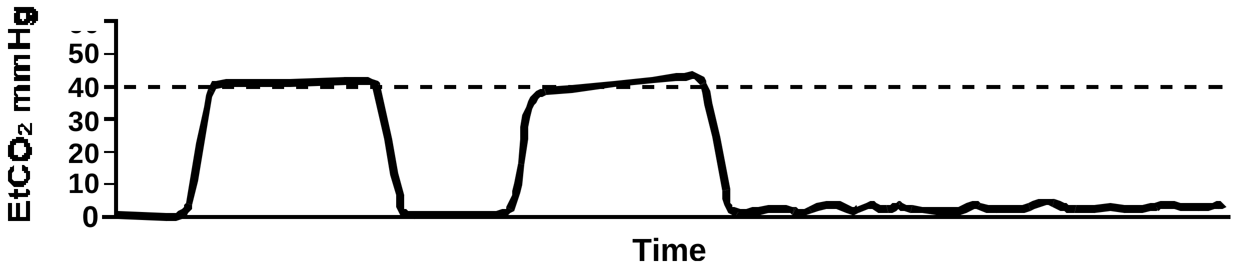
Presentation

You and your partner are working a cardiac arrest and are successful in resuscitation. The Patient is still unstable and the decision is made to load and go because of the very short transport time to the ED. He is intubated and $EtCO_2$ confirmed with good waveform and an $EtCO_2$ of about 42mm/hg.
The patient is not breathing on their own.

Clinical Situation:



B/P is 100/70
Pulse is 88
RR assisted
SpO_2 is 100% on 15lpm via NRB mask
$EtCO_2$ is 40-42
After loading him into the ambulance, the first responders resume ventilation. The capnography alarm sounds and the following waveform is seen:



CASE # 3 Continued

Questions:

Is the $EtCO_2$ within normal limits?

Is the waveform normal or abnormal? Why or Why Not?

What can you deduce about the ventilation status?
A
B
C

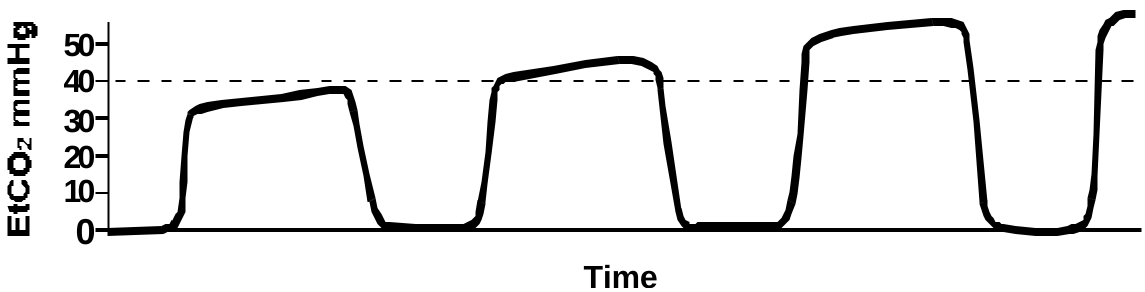
CASE # 4

Presentation

You have a 30-year-old female who was in status seizures. Your partner administers Valium to halt the seizures. The patient appears to be post-ictal but is slow to respond fully.

Clinical Situation

B/P is 114/68
Pulse is 96
RR is 12
SpO_2 is 98 on 6 lpm nasal cannula
Glucose is 100
$EtCO_2$ is as follows



Questions:

Is the $EtCO_2$ within normal limits?

Is the waveform normal or abnormal? Why or Why Not?

What can you deduce about the ventilation status?
A
B
C

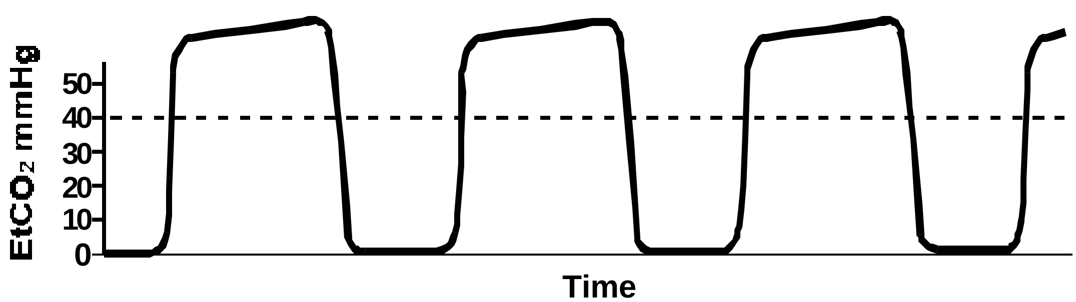
CASE # 5

Presentation

It's 3 am and you are called to a residence for a 60 year old man that is in respiratory distress. You find the gentleman sitting up on his bed with feet dangling off the end. He presents in obvious distress and cannot speak words due to the distress. His lung fields are very diminished with crackles heard. He is pale and diaphoretic and appears to be getting weaker. Family members tell you that he has a bad heart and takes a "heart pill", and a "water pill". Pt becomes obtunded with labored breathing. They still have a gag reflex.

Clinical Presentation

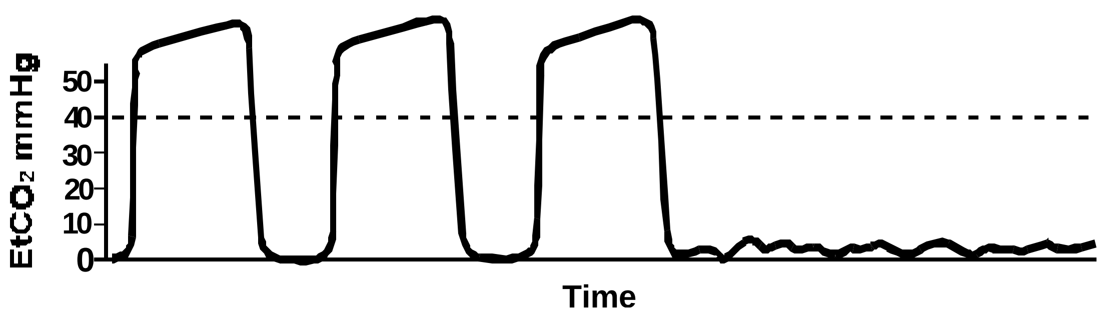
BP is 158/90
HR is 130
RR is labored
SpO_2 is 88%
$EtCO_2$ as follows



A
B
C

Case #5 Continued

The decision is made to nasally intubate this patient. The tube is passed although the lung sounds are so diminished they are hard to hear. The Pulse Ox offers no change, however, the capnogram shows the following:



Questions: Scenario 5

Is the $EtCO_2$ within normal limits?

Is the waveform normal or abnormal? Why or Why Not?

What can you deduce about the ventilation status?

A

B

C

Closing Remarks,
…From one paramedic to another….

Capnography represents another great stride in the advances in technology and medicine that have made way into the field. Not since the cardiac monitor and paramedics manually reading ECG strips has one device had the ability to benefit such a wide variety of patients.

For years, Anesthesiologists have used waveform capnography as their standard for monitoring the vital functions of patients. Now, the technology allows a smaller version to be used by paramedics.

And now, YOU are ready to do this! Think of the incredible difference this can make in the care of your patients.

To summarize, why do you need waveform capnography?

- Ventilation Vital Sign
- Confirmation of tube placement
- Constant monitoring of airway, ventilation and perfusion
- Bronchoconstriction in Obstructive airway disease
- Any respiratory patient
- Closed head injury to guide the careful elimination of CO_2
- Progressive monitoring of perfusion and ventilation

Why a color change device isn't enough

- Only confirms the presence of CO_2 not the amount
- Can't monitor the patient

Why a quantitative device is not enough

- While a number is better than just a color change,
- It can't detect bronchoconstriction
- It can't trend the level of CO_2

There are many different brands and technology out there. I have tried to present a fair and unbiased account of my extensive research into the subject. Take each device for a "test drive" and make your mind up.