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Advanced Case Concepts Capnography

Virginia EMS Symposium 2012

Objectives

- Brief Review Capnography
  - History
  - Anatomy and Physiology
- Case Presentations
  - Pathophysiology of Respiration and Ventilation
  - Capnography integrated with the critical care patient
  - "Advanced" application of capnography
  - Alternative Applications

Capnography 2010

- BLS Skill with placement of blind rescue airways
  - King LTD
  - Combitube
- Applies to any ventilated patient
  - Bag-mask
  - ETI and rescue airways
  - Transport vent
  - CPAP?
- Noninvasive applications

Capnography 2010

- New AHA Guidelines
  - New this month
- Quantitative,continuous capnography
  - Monitor position of airway devices
  - Quality of CPR
- "CAB"
  - Circulation-Airway-Breathing

First Priority

- Maintenance of Intubation
  - Confirm and re-confirm placement
  - Visualization
  - Auscultation
  - Observation
- Quality of Ventilation
- Capnography:
  - “Memorial, we have confirmed tube placement with a BEAUTIFUL BOX SHAPED waveform at 35 to 40!”

Intubation Confirmation

- When you put the tube in the trachea
  - Watching it pass through the cords
- When your assistant moves the BVM the wrong way
  - When the hairs on you neck stand up
- When you move the patient
  - From the house, to the stretcher, to the ambulance, to the hospital, on the code bed

Capnography

- Quantitative, graphical measurement of instantaneous CO_2 concentration
- American Society of Anesthesiologists (ASA) standards:
  - *Every patient receiving anesthesia shall have adequacy of ventilation continually evaluated*
  - *Continual monitoring for the presence of expired carbon dioxide shall be performed unless invalidated by the nature of patient, procedure, or equipment*
  - *Continual $EtCO_2$ analysis, in use from the time of ET placement, until extubation/removal or transfer …shall be performed using a quantitative method, such as capnography, capnometry, or mass spectroscopy*

EVERY INTUBATED PATIENT..

Continuous Monitoring…

Quantitative..

History of Capnography

- Developed in 1961 (For practical purposes)
- Expensive and bulky product limited to OR anesthesia
- In mid 1980s, anesthesia related fatalities led to need for improvements in airway management
  - Malpractice costs rise 1975 to 1985

History of Capnography

- 1988: Anesthesia standardized use of pulse oximeters and capnography
  - Malpractice claims from hypoxic related injury almost eliminated -Massachusetts
  - Insurance claims from anesthesia drops from 11% to 3% over 15 years
  - In 2002, anesthesia insurance premium was $18,000, the same as it was in 1985

Integration of Capnography

- In Anesthesia, capnography is an industry standard
- In EMS, it is a standard, but not there are variables
  - “No, its not the pulse ox!”
  - Waveform versus colormetric
- It is not common in Emergency Departments, and varied in ICUs

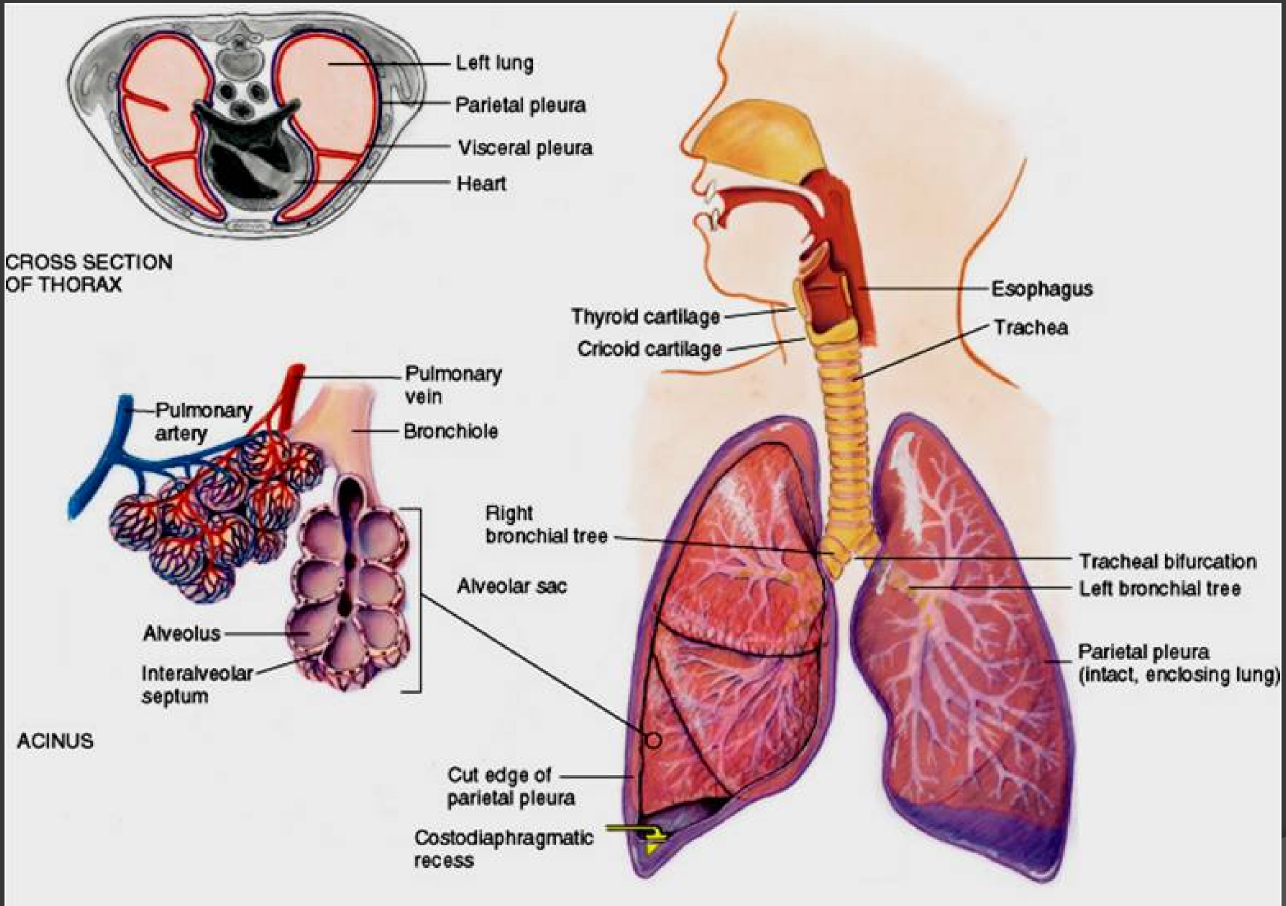
PATIENT SAFETY

ABOVE ALL, DO NO HARM

A&P for Capnography:

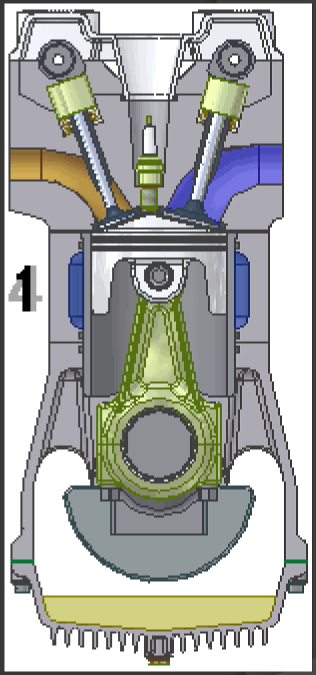
- What is important:
  - Air movement
  - Surface area of lungs
  - Blood flow to lungs and body
- Respiratory Cycle
  - Alveolar level
  - Cellular level

Respiratory Anatomy



Review of Metabolism

- Aerobic:
  - Oxygen and Glucose metabolize to produce Energy to do work
  - Carbon Dioxide and Water are the byproducts
  - Krebs Cycle
  - Most efficient process
    - Improves with exercise



Review of Metabolism

- Anerobic:
  - Lack of oxygen causes build up of acids
  - Lactic Acid and Pyruvic Acid
- Buffer System
  - Hydrogen Ions of the Acid (pH) combine with Bicarbonate to form Carbonic Acid
  - This breaks down into water and carbon dioxide
  - Increased CO2 stimulate increased ventilation rate to remove it

Carbon Dioxide

- By-product of normal respiration
- Measured as a Partial Pressure
  - 35-45 Mm/Hg
- Measured as a Percentage
  - 5-6%
- Key for: respiratory drive, ph balance
- Considered “acidic”

Drive to Breathe

- CO_2 triggers breathing
- NOT ENOUGH
  - Hypoventilation leads to hypercarbia
  - Hypercarbia leads to respiratory acidosis
- TOO MUCH
  - Hyperventilation leads to hypocarbia
  - Hypocarbia leads to respiratory alkalosis

What do the numbers mean?

- Oxygen and Carbon Dioxide
- Hypoventilation:
  - $O_2 < 60$mm/Hg
  - $CO_2 > 45$mm/Hg (Hypercapnea)
- Hyperventilation:
  - $O_2 > 100$mm/hg (SaO_2 above 98%)
  - $CO_2 < 35$mm/Hg

CO_2 on the BRAIN

- Decreased CO_2 from hyperventilation
  - Cerebral Vasoconstriction
  - Balancing
- Indication: (old school)
  - Traumatic head injury/CVA
  - Maintain perfusion without worsening bleeding
    - End-tidal CO_2 target is 33 to 35mm/Hg

CO_2 on the Brain

- Elevated CO_2
  - Permissive Hypercarbia
  - Above 45mm/Hg
  - With adequate oxygenation
- Potential Benefits
  - Cerebral and systemic vasodilation
  - Increase cellular oxygen supply
  - Decrease oxygen demand

Priority is Oxygenation

- Adequate Oxygenation
- Adequate Ventilation
- Avoid tunnel vision
  - Use your tools
- Quality over Quantity

HYPOXIA KILLS

Dalton's Law: Partial Pressure of Gas

Total pressure of a gas is equal to the SUM of the partial pressures of the gas

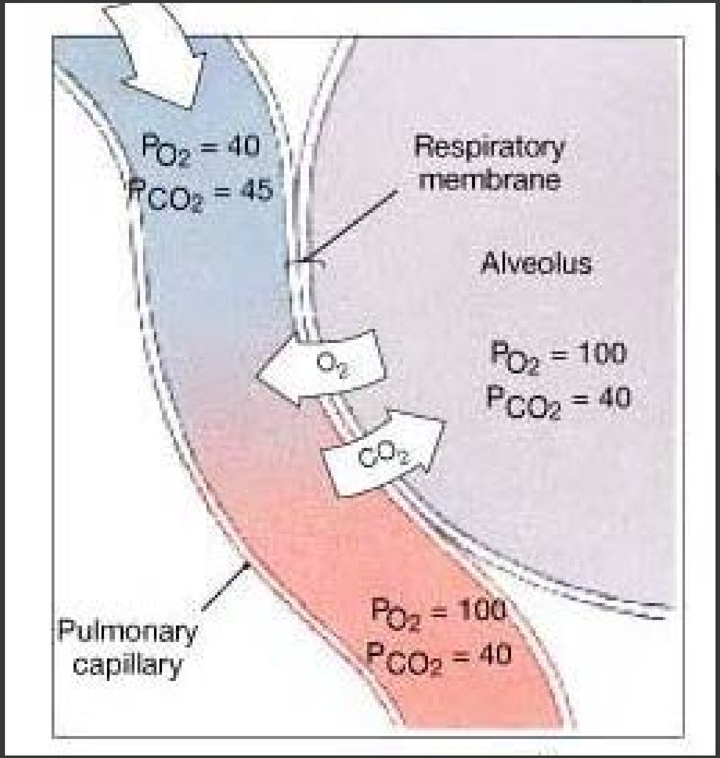
- Atmospheric pressure is 760mm/Hg at sea level
- Under NORMAL conditions, all of the atmospheric gas pressures add up to 760
  - Oxygen is 159.2 mm/Hg
  - Nitrogen is 592.8 mm/Hg
  - CO2 is 0.23 mm/Hg
  - Other gases, like Argon = 8mm/Hg

Atmospheric Gases

- Convert percentage to pressure
- Normal gas Percentage
  - Oxygen at sea level: 21%
  - CO2 and other gases: 1%
  - Nitrogen: 78%

Partial Pressure

- Gradient
- The exchange of gases based on pressure gradient
  - Pressure forces Oxygen onto Hemoglobin

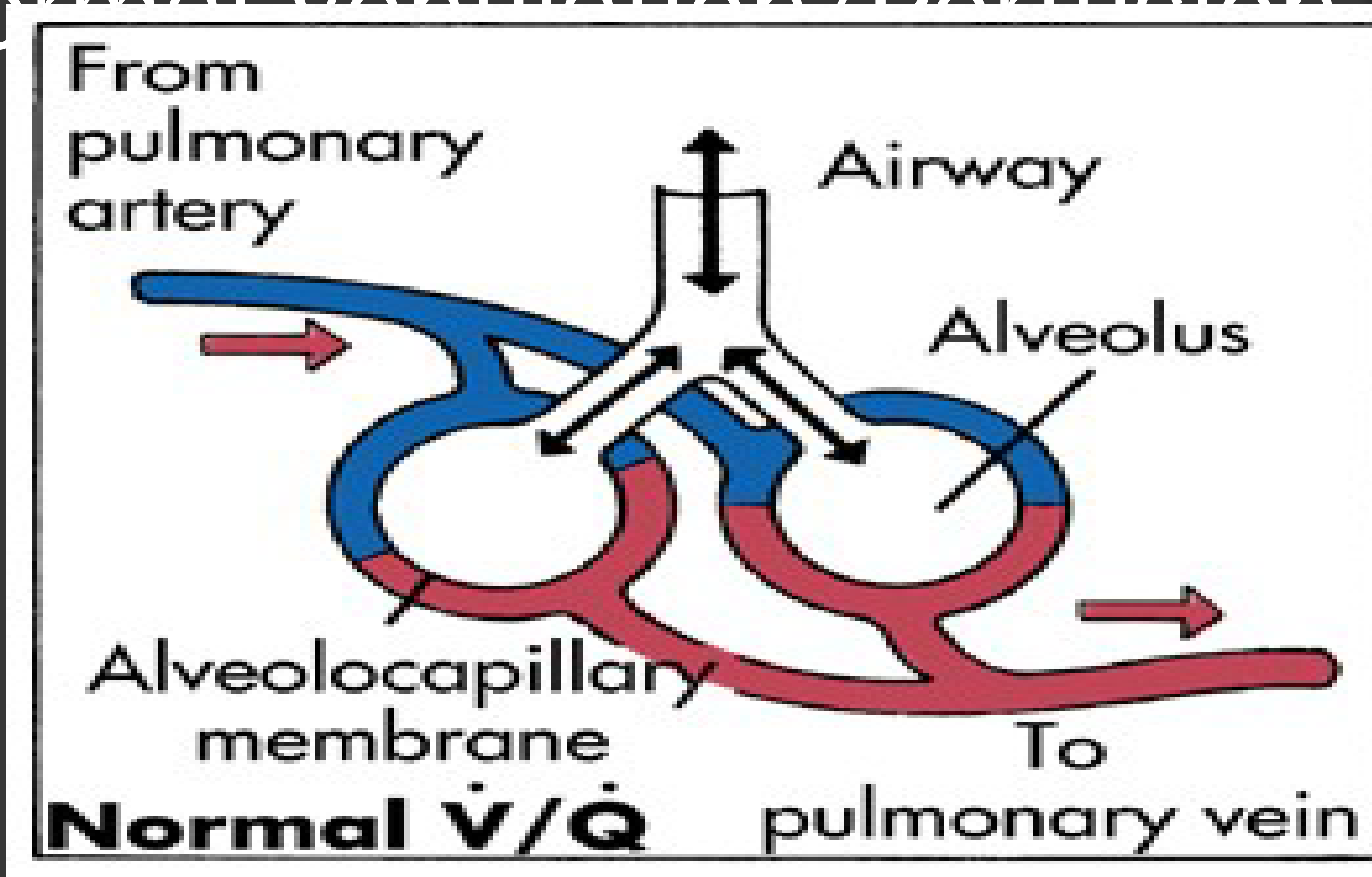


Ventilation and perfusion

Pathology that Impacts CO2

- Ventilation Problems
  - Inability to move air in and out of the alveoli
  - Hyperventilation, hypoventilation
- Perfusion Problems
  - Oxygen transport to cells
  - Lack of blood flow
  - Ability of blood to carry oxygen

Normal Ventilation /Perfusion



Alveolar Perfusion Problems

- Shunt Problem
  - Blocking of bronchial airways
    - Pneumonia, atelectasis
    - Right mainstem intubation
  - Causes retention of CO_2, increased levels
- Dead Space Ventilation
  - Capillary flow to alveoli impaired
    - Low Cardiac output, hypotension
    - Excessive PEEP
  - CO_2 does not cross into the alveoli for exhalation
  - Decreased levels of CO_2

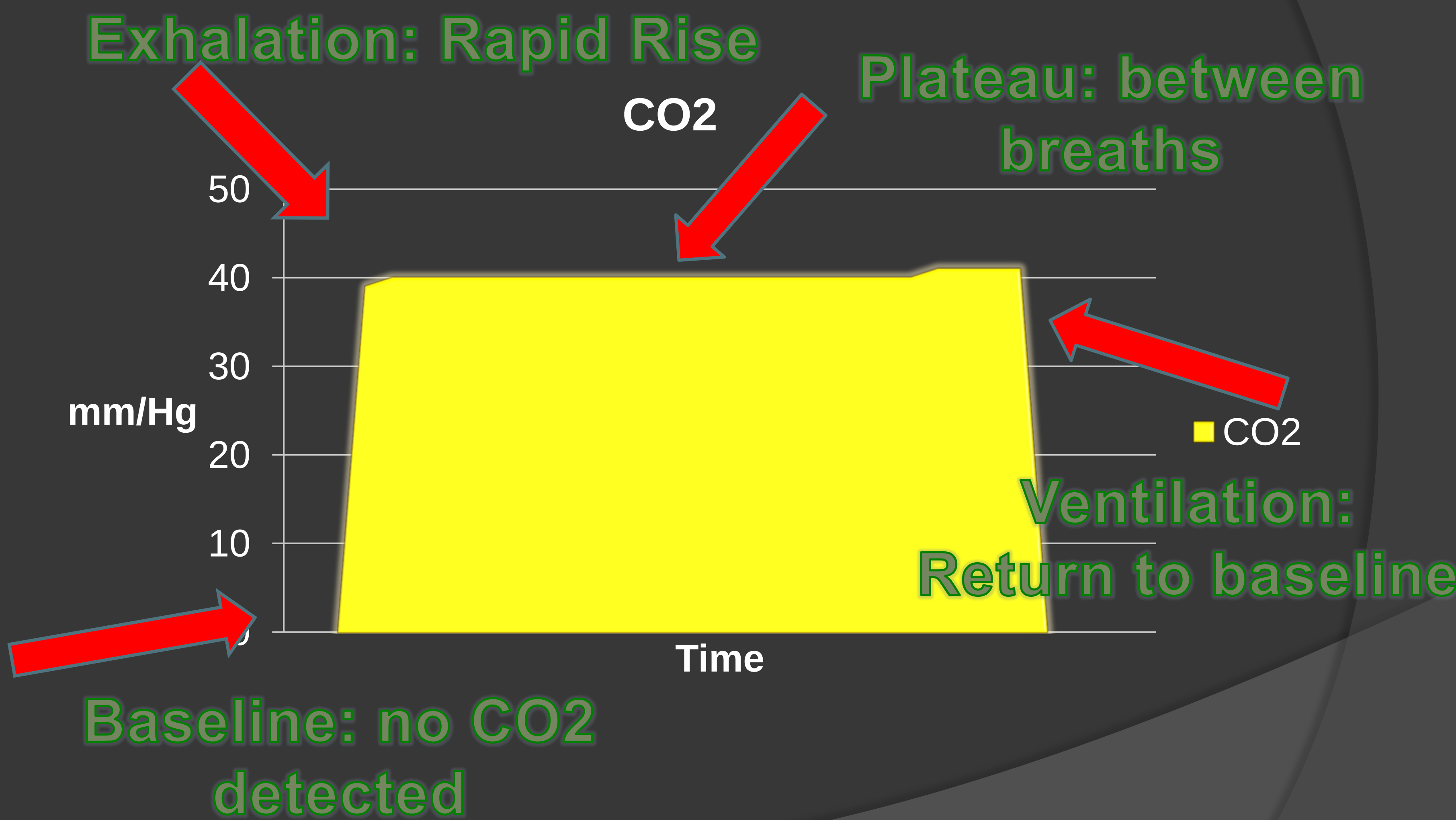
Clinical Conditions: Increased CO_2

- Increased CO_2 production
  - ***Bicarbonate administration, fever, seizures, sepsis, thyroid storm***
- Decreased alveolar ventilation
  - ***Hypoventilation, muscular paralysis, respiratory depression, COPD (retaining CO_2)***
- Equipment Problem
  - ***Rebreathing, ventilator leak***

Clinical Conditions: Decreased CO_2

- Decreased CO_2 production
  - ***Cardiac arrest, hypotension, hypothermia, pulmonary emboli, pulmonary hypoperfusion***
- Increased alveolar ventilation
  - ***Hyperventilation***
- Equipment Problems
  - ***Airway obstruction, esophageal intubation, ETT leak, incomplete exhalation, poor sampling, ventilator disconnect***

Normal EtCO2 waveform



Sidestream vs. Mainstream

Sidestream

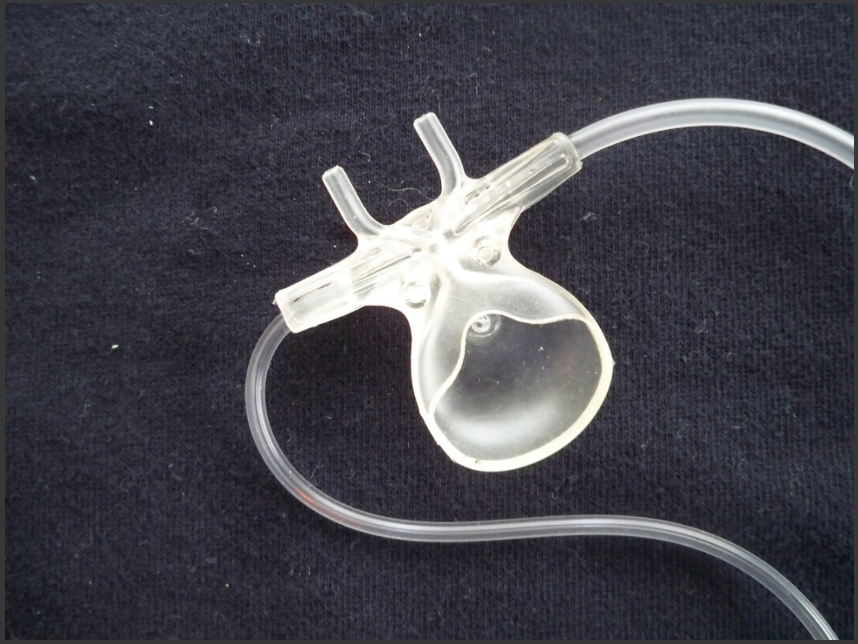
- Sensor is located in device like LP12, or extension, like Zoll E
- Adapter tube attaches to ETI
- Pump in machine pulls air in for measurement
  - 100 to 150 ml air in early devices
  - 50 ml in Microstream
- Concerns:
  - Delay of 3-5 seconds
  - Quality of sample

Sidestream

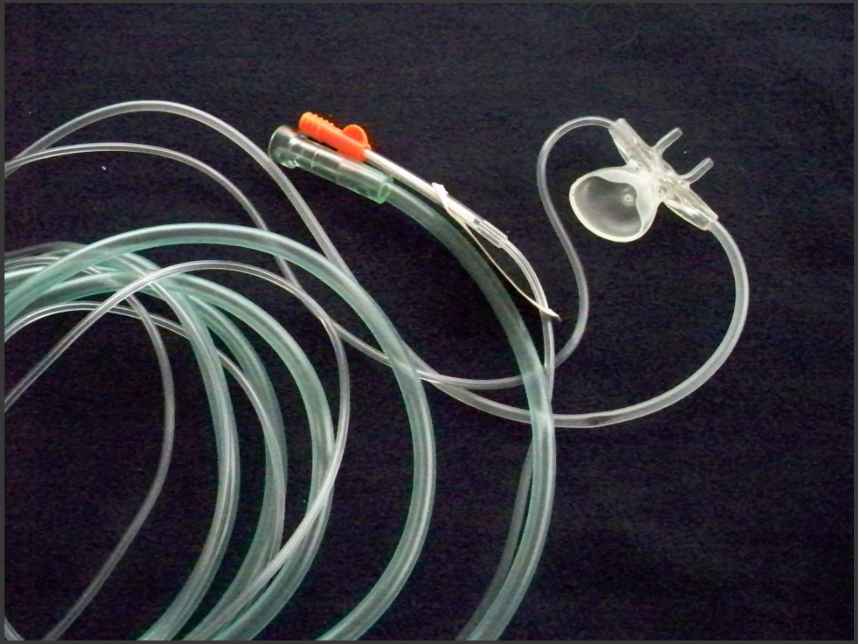
- Easier to use non-invasively
- Key is quality of the patient's respirations
  - Shallow is poor
  - Mouth breathing is challenging
  - Newer devices assist in increasing accuracy
- Sidestream is LESS specific because of its engineering

Side-stre

Sidestream Detector



Cannula with mouth scoop



Oxygen and sensor

Mainstream Detector

- Sensor at end of cable
  - Disposable adapter to ET tube
- "Real time" values-best for critical care
  - As the gas passes the IR sensor
- Concerns:
  - Not easily adapted to non-intubated patient
  - Can be heavy for pediatric of infant ET tubes
  - Cable is expensive

Mai

Troubleshooting

- False Positive
  - Large amount of carbonated beverage
    - AHA
  - Rapidly Declines
- False Negative
  - More common
  - Low flow states
    - Air movement
    - Blood Flow

Troubleshooting

- Sudden loss of waveform
  - IMMEDIATE CLINICAL RECONFIRMATION
  - Lung sounds, SaO2, Anything else
- Place colormetric detector
- Clean/Clear sensor
  - Blockage
- Recalibrate/zero if able
- Replace adapter

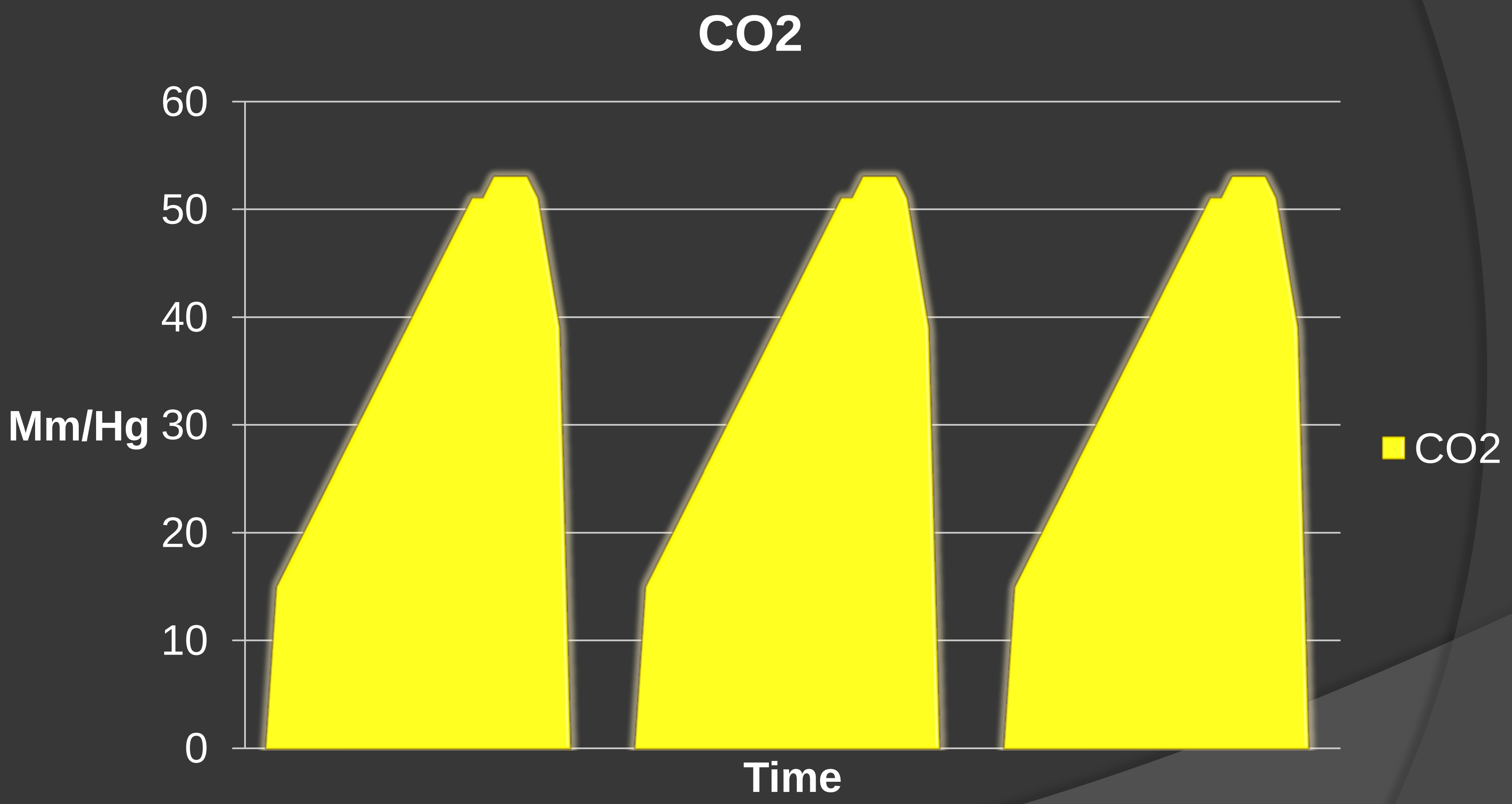
Case Presentations

- What are you seeing?
  - What does your physical assessment tell you?
- What are your transport considerations?
  - Interventions
- Differential Diagnosis?
- Trouble shooting?
  - Is the data valid?

Case 1

- Respiratory Distress
- 54 y/o COPD
- Respiratory Rate: 24
- Pursed lips

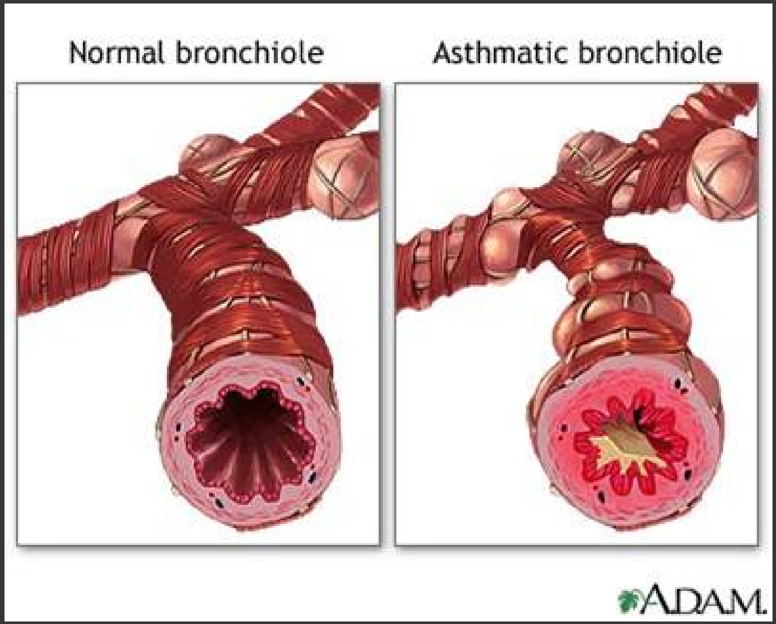
Case 1

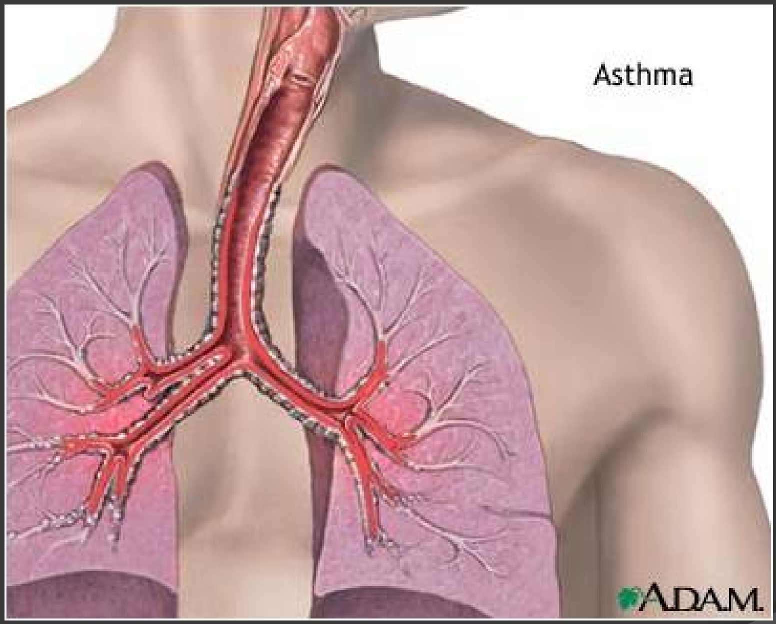


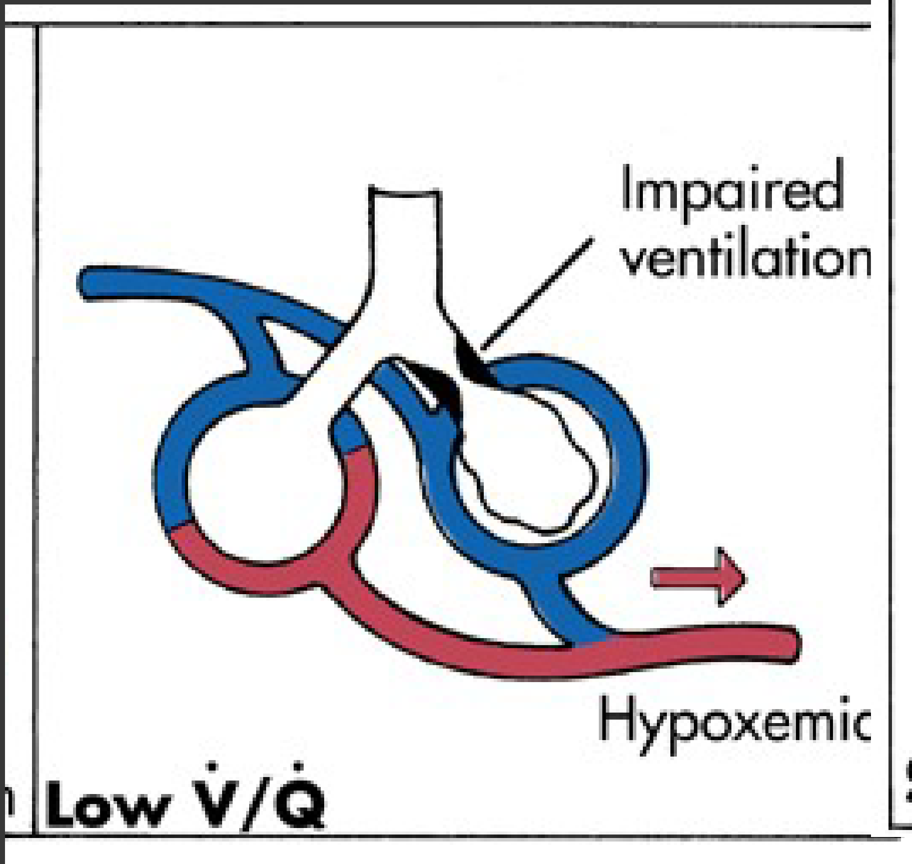
Obstructive Airway Disease

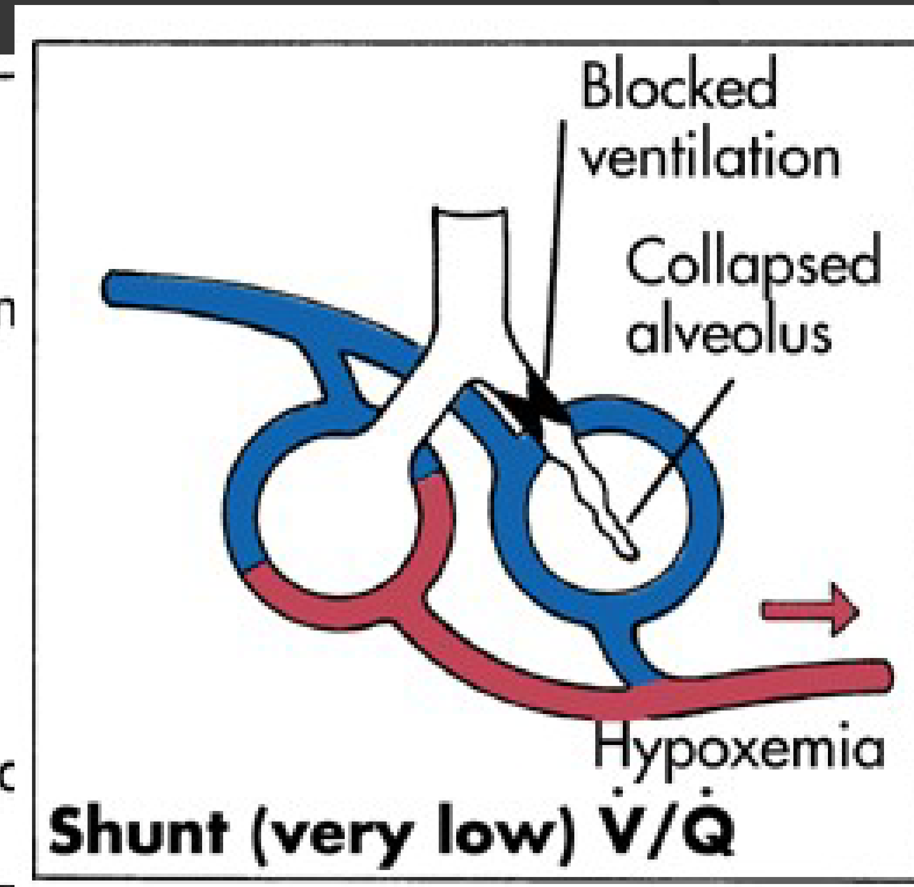
- Shunt problem
- Asthma, COPD, Emphysema
  - Swelling of airways/excess mucus
  - Airflow turbulent
  - Forceful expiration
- Different EtCO2 presentations:
  - Mild=hyperventilation, low EtCO2
  - Moderate=normal EtCO2, waveform change
  - Severe=elevated EtCO2, sharkfin

Asthma Pathology



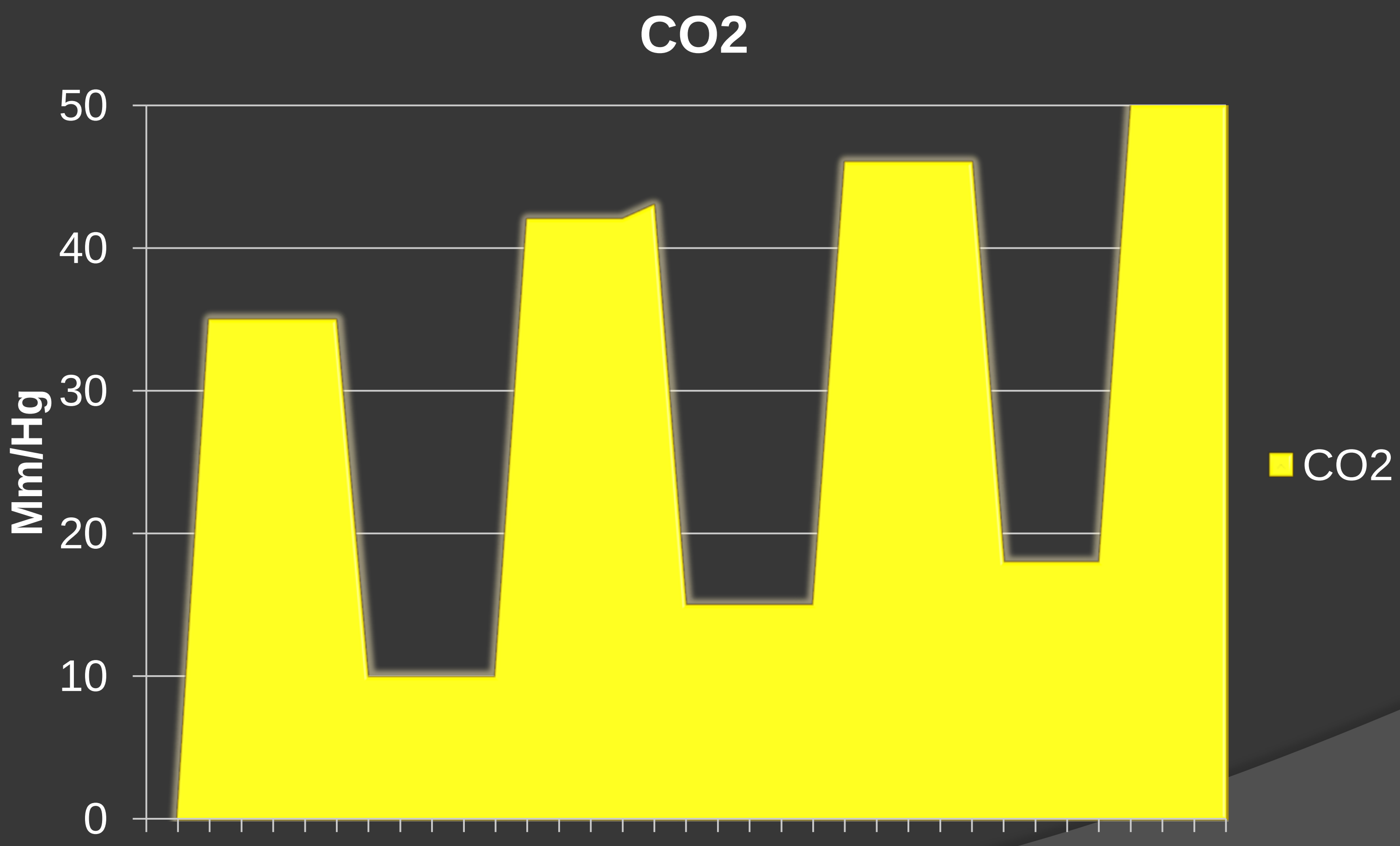






Impaired Ventilation
Shunt Problem

Case 1 Variant



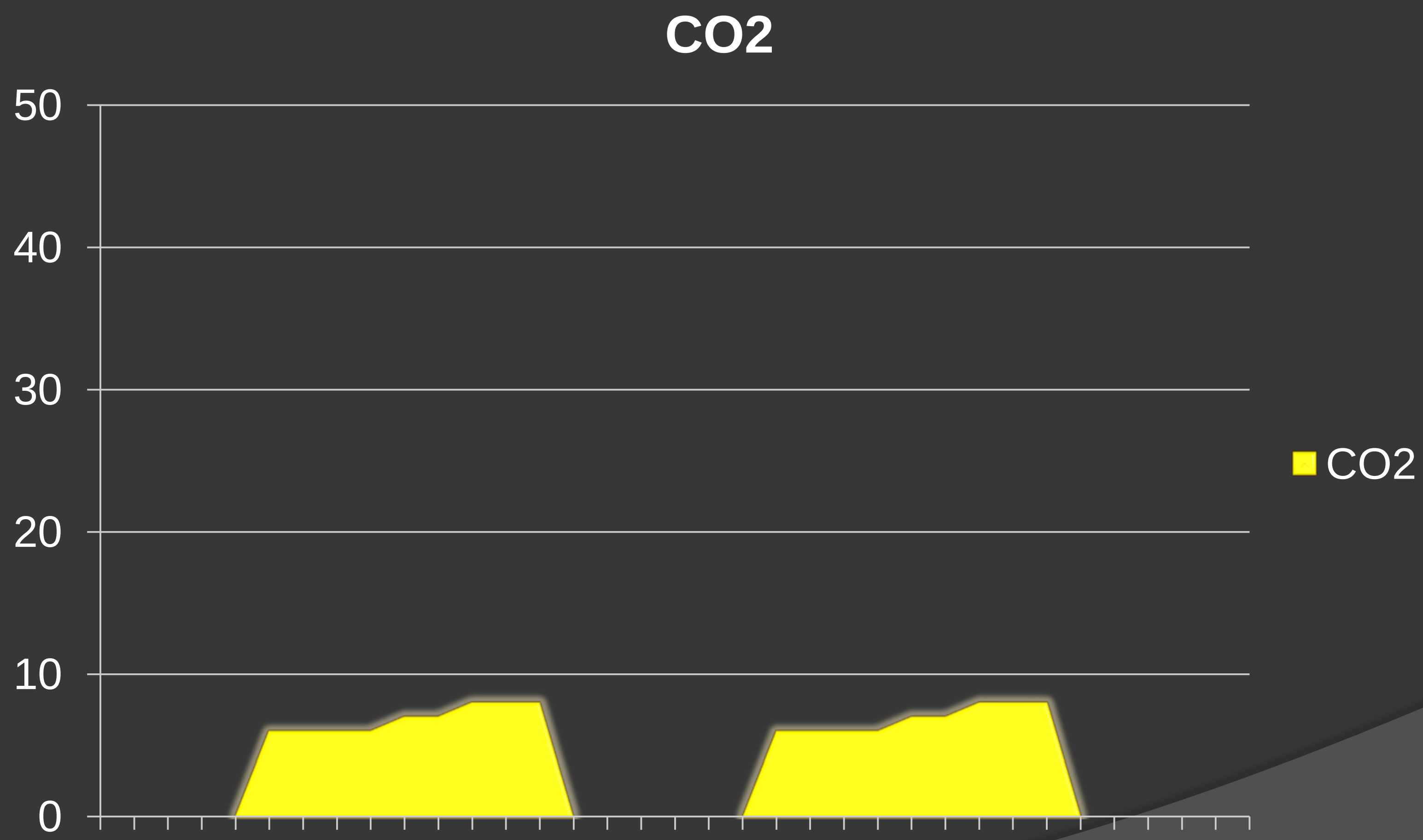
Case 2

- 65 year old obese trauma patient
- Predicted Difficult Intubation
- Multiple Injuries
  - Chest Contusions
  - Abdominal Distention
  - Fractures of right upper leg, left lower leg, and right arm
- Complains of Respiratory Distress

Case 2

- Initial Et CO_2 6-7mm/Hg
- Intermittent sensor detection of numerical value
- Waveform present
- Low “shark fin” appearance
- What is going on?
- Is the ET good?

Case 2



Shock

- "A rude unhinging of the Machinery of Life"
  - Samuel Gross, 1872
- "A momentary pause in the act of death"
  - John Collins Warren, 1895
- "Pushing back the edge of death"
  - Judy Mikhail, 1999

Shock

- As the body's compensatory mechanisms begin to work, we appreciate changes in vitals signs:
  - Altered mental status
  - Pale, clammy, diaphoretic
  - Increased heart rate and respiration
  - Decreased blood pressure

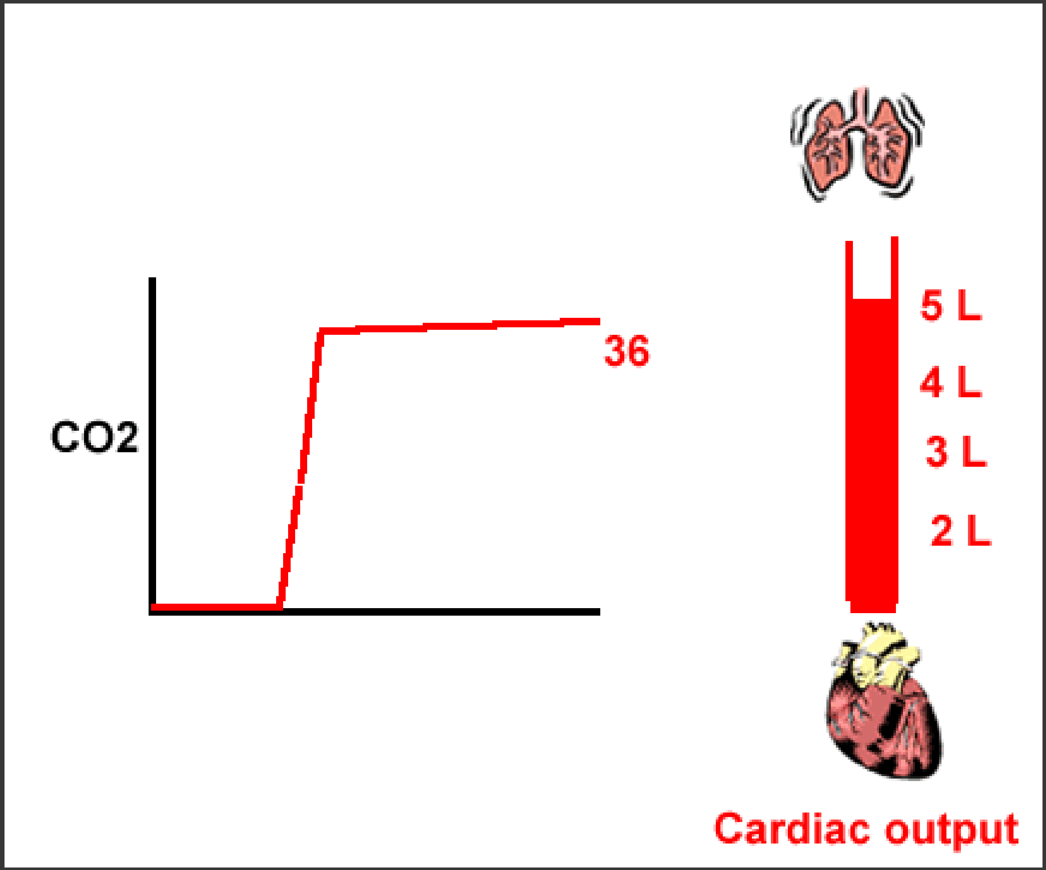
Shock and Capnography

- A Piece of the Puzzle
- Anaerobic compensation for decreased perfusion:
  - CO_2 elevated, ventilations increase
- Cardiac Output drops:
  - Vasodilation or from hypovolemia:
  - CO_2 decreased as detected by $EtCO_2$

Shock

- Capnography:
  - Index of Resuscitation
  - Quality of perfusion
  - Quality of ventilation
- Like ALL monitors, it is a TOOL
  - Understand its limitations
  - It can GUIDE decisions
  - It should not MAKE the decision

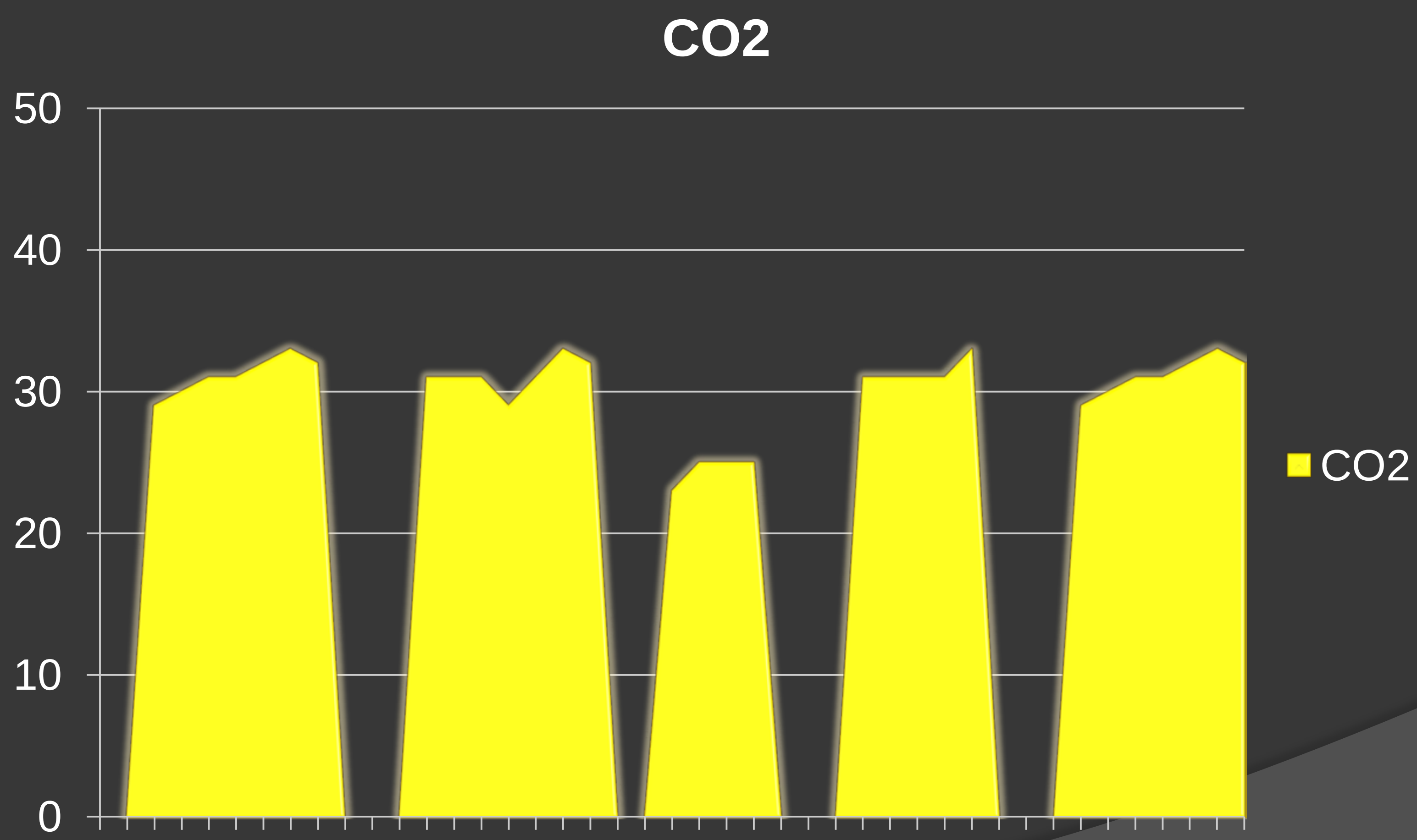
Cardiac Output and CO2



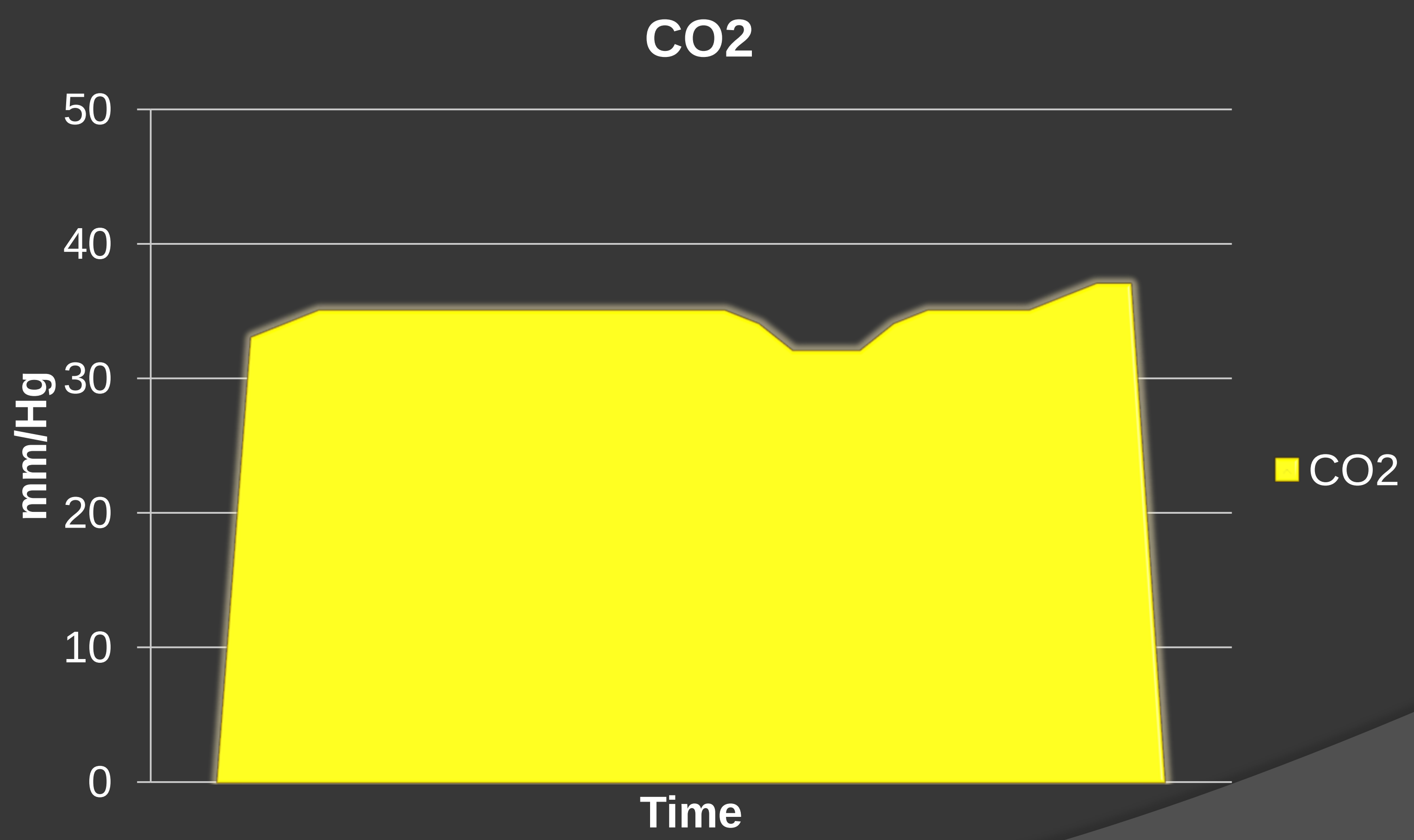
Case 3

- 26 year old MVC at community hospital
- Intubated in ED after becoming combative
- Vitals: Respirations 20 assisted on ventilator
- Assist/Control:
  - Rate12, TV 500, FiO2 50%, PSV 10, PEEP 5

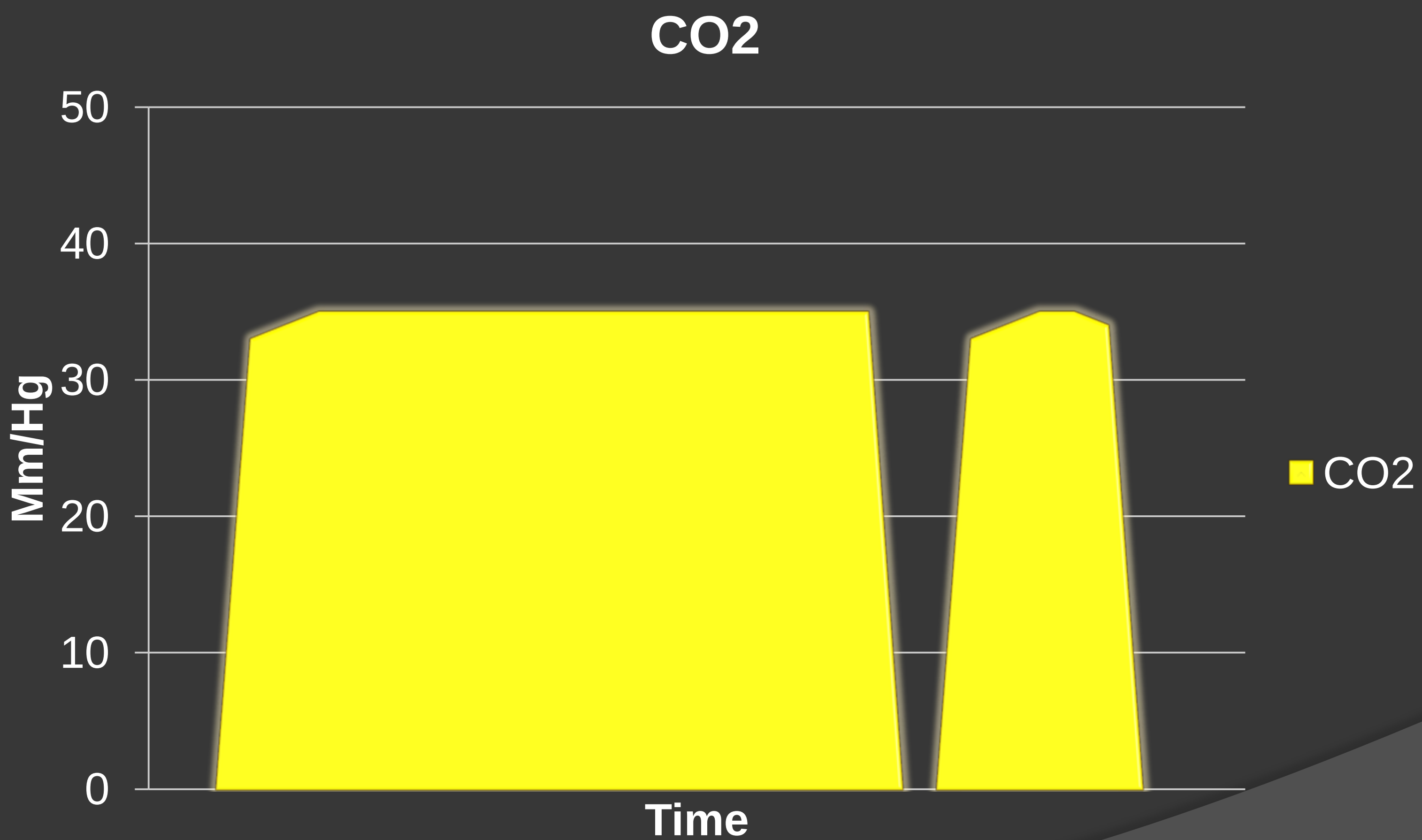
Case 3



Case 3



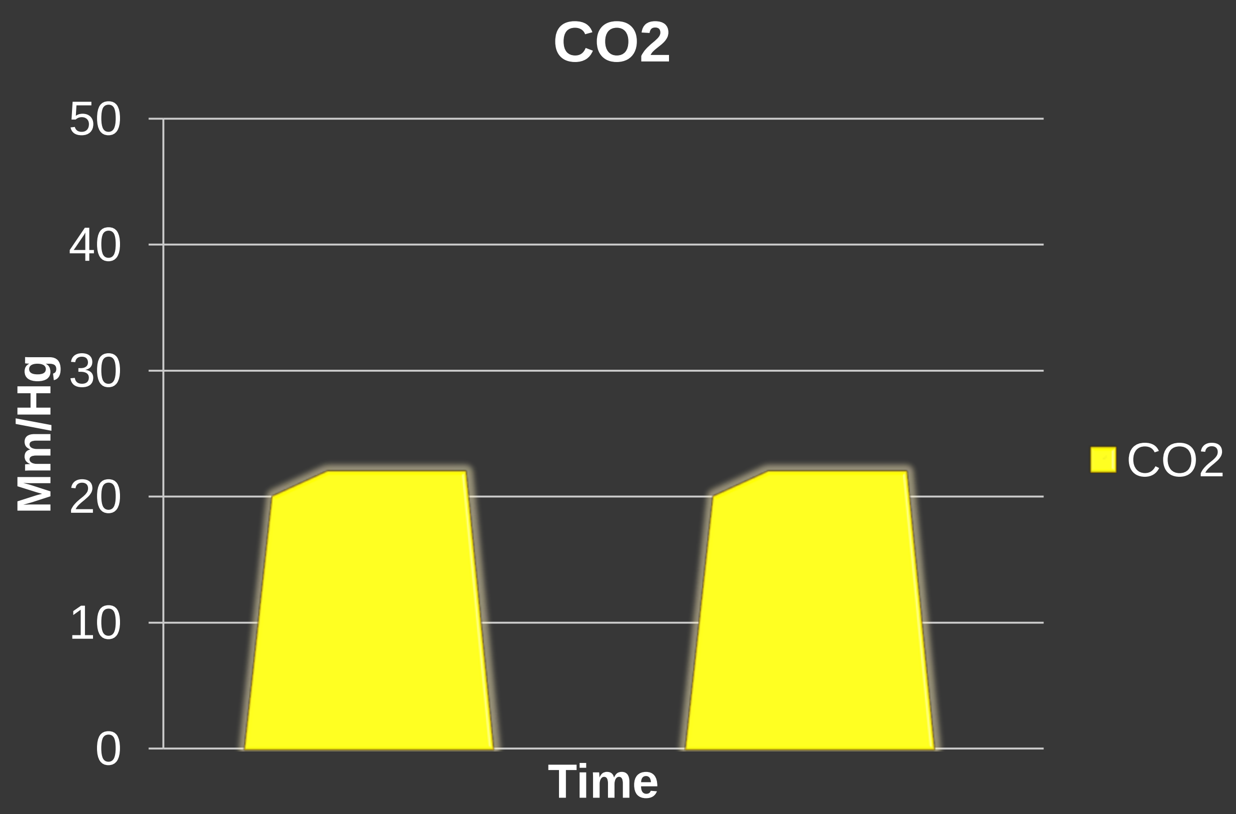
Case 3



Case 4

- 50 year old cancer patient receiving radiation and chemo
- Presents with respiratory distress to ED
  - SaO_2: 85%, dramatic work of breathing, becoming tired
  - intubated promptly, placed on ventilator
  - Vitals: BP 140/88, HR 78, vented at 10 with SaO_2 of 93% with 100% FiO_2
  - Initial $EtCO_2$ is 20mmHg

Case 4



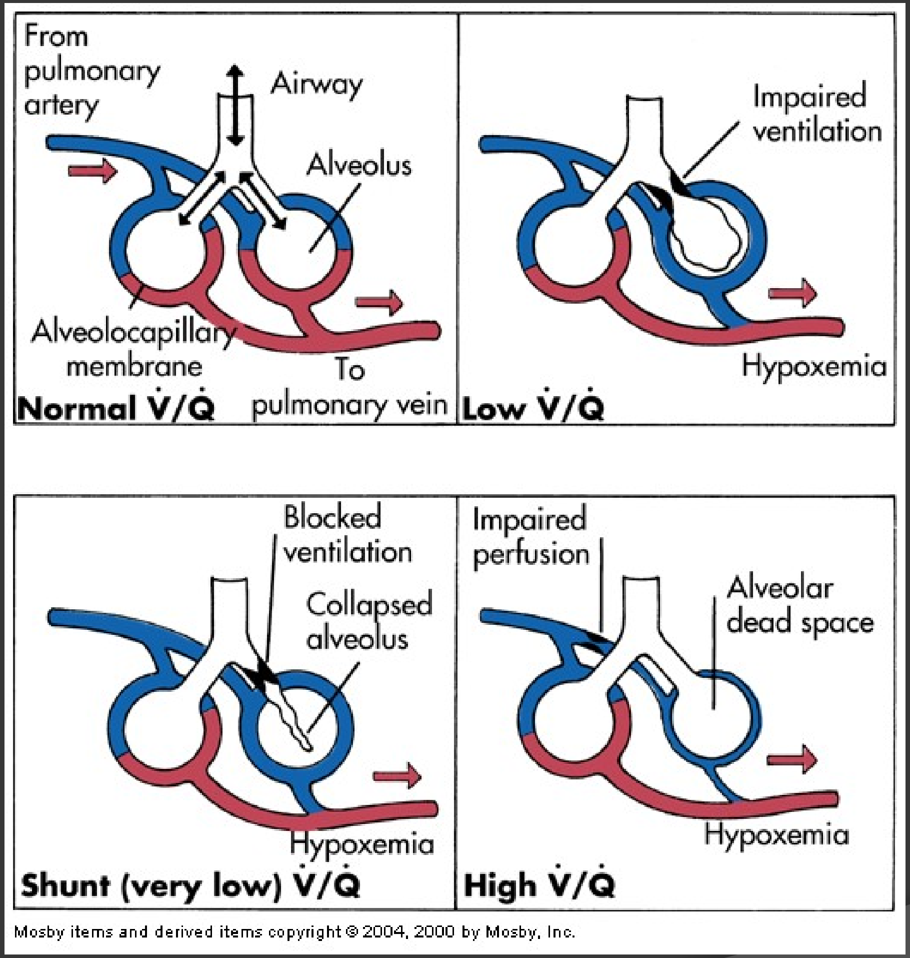
Case 4

- Community ED requests transfer to tertiary care for Pulmonary Embolism
- Post Intubation ABG:
  - pH 7.31, PaO_2: 140, $PaCO_2$: 49mmHg, Bicarb 27
- CO_2 gradient:
  - $PaCO_2$ – $PetCO_2$ (49 minus 20 equals 29mmHg)
  - Normal gradient 3 to 5mmHg
- What is in the blood is not getting out

Pulmonary Embolism

- Dead Space Ventilation
  - Decreased EtCO2
- Clot breaks loose in blood vessel
  - Floats to and obstructs pulmonary vasculature
- Causes:
  - Post surgical
  - Sitting for extended time
  - David Bloom, NBC News in 2003

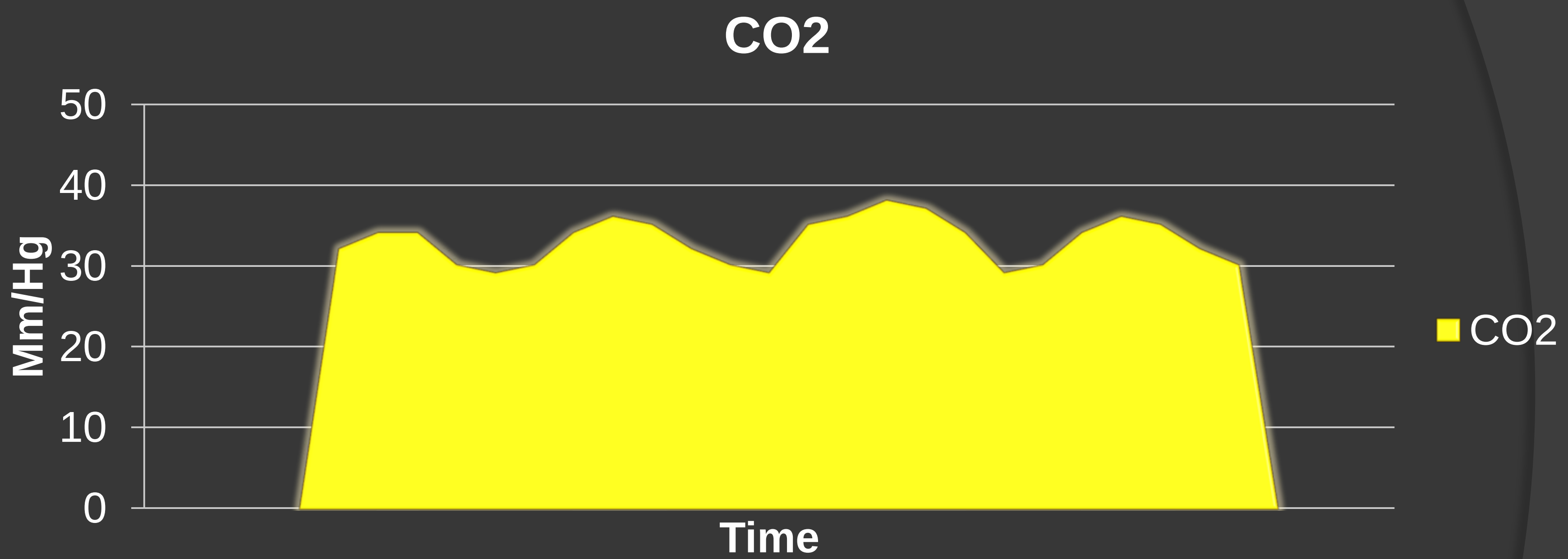
Dead Space Ventilation



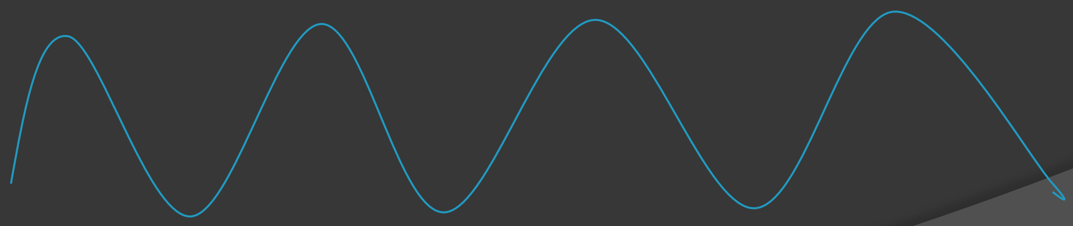
ABGs, pH, and Capnography

- Arterial Blood Gases assess for acid-base balance
  - Acidosis and Alkalosis
  - Mechanisms: Respiratory and Renal (Metabolic)
- pH is a measure of Hydrogen ion concentration (H+)
  - Normal is 7.35 to 7.45
  - Reflects balance between carbon dioxide and bicarbonate
- Capnography only represents the

Varient

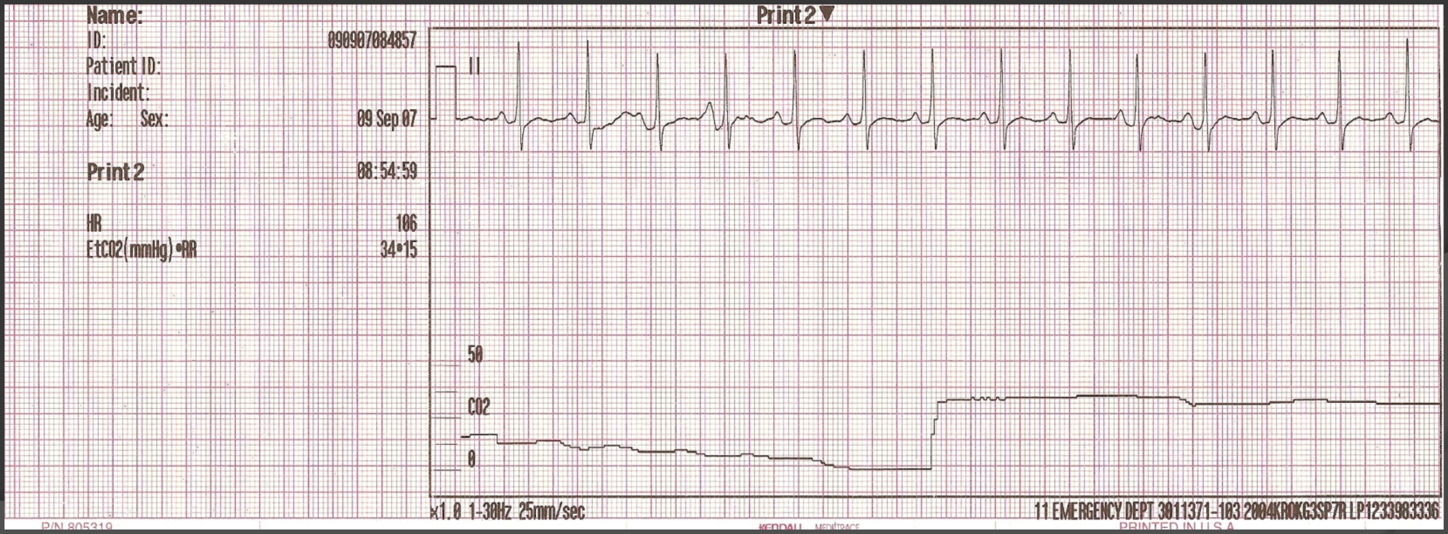


Pulse
Oximetry

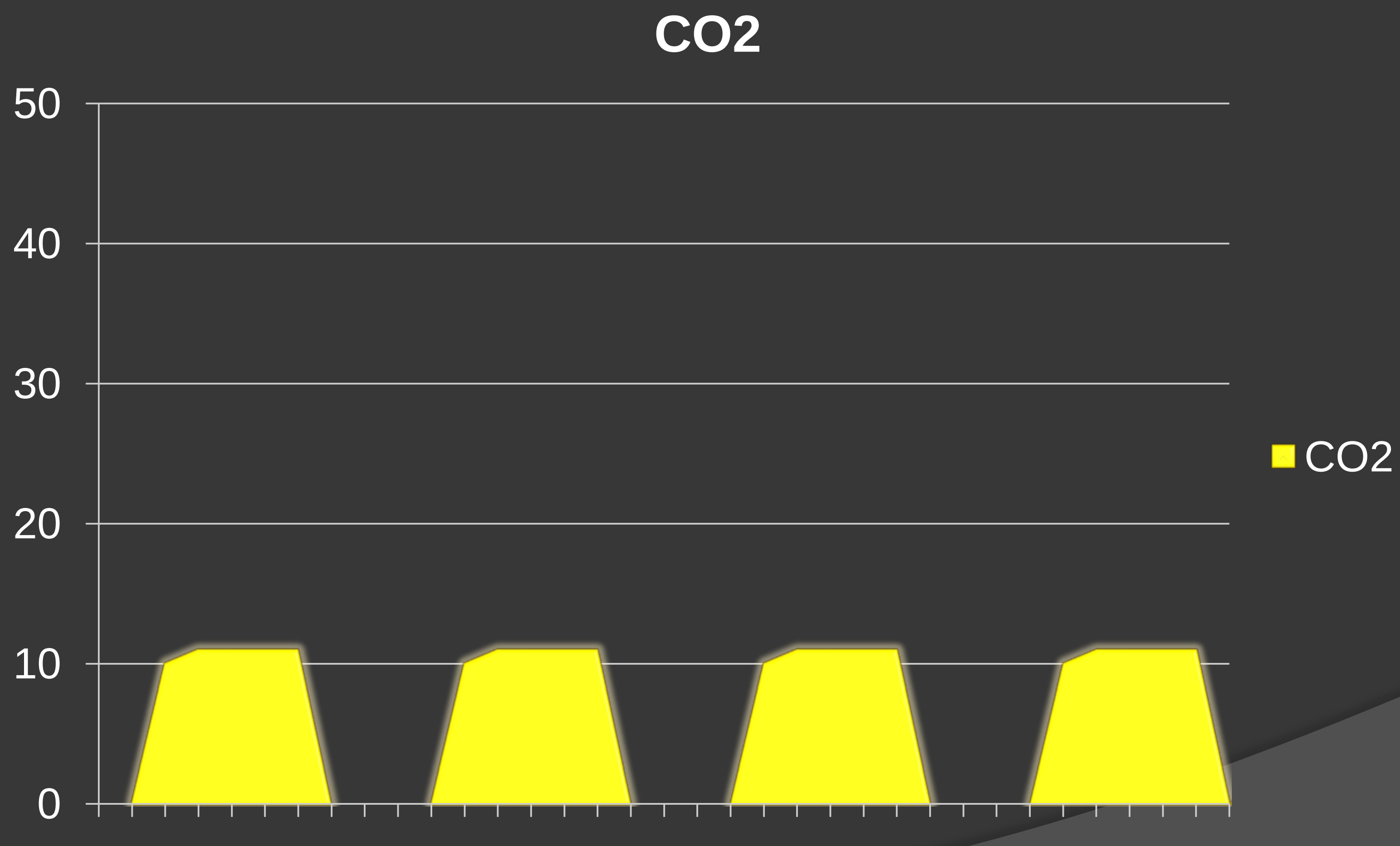


Case 5

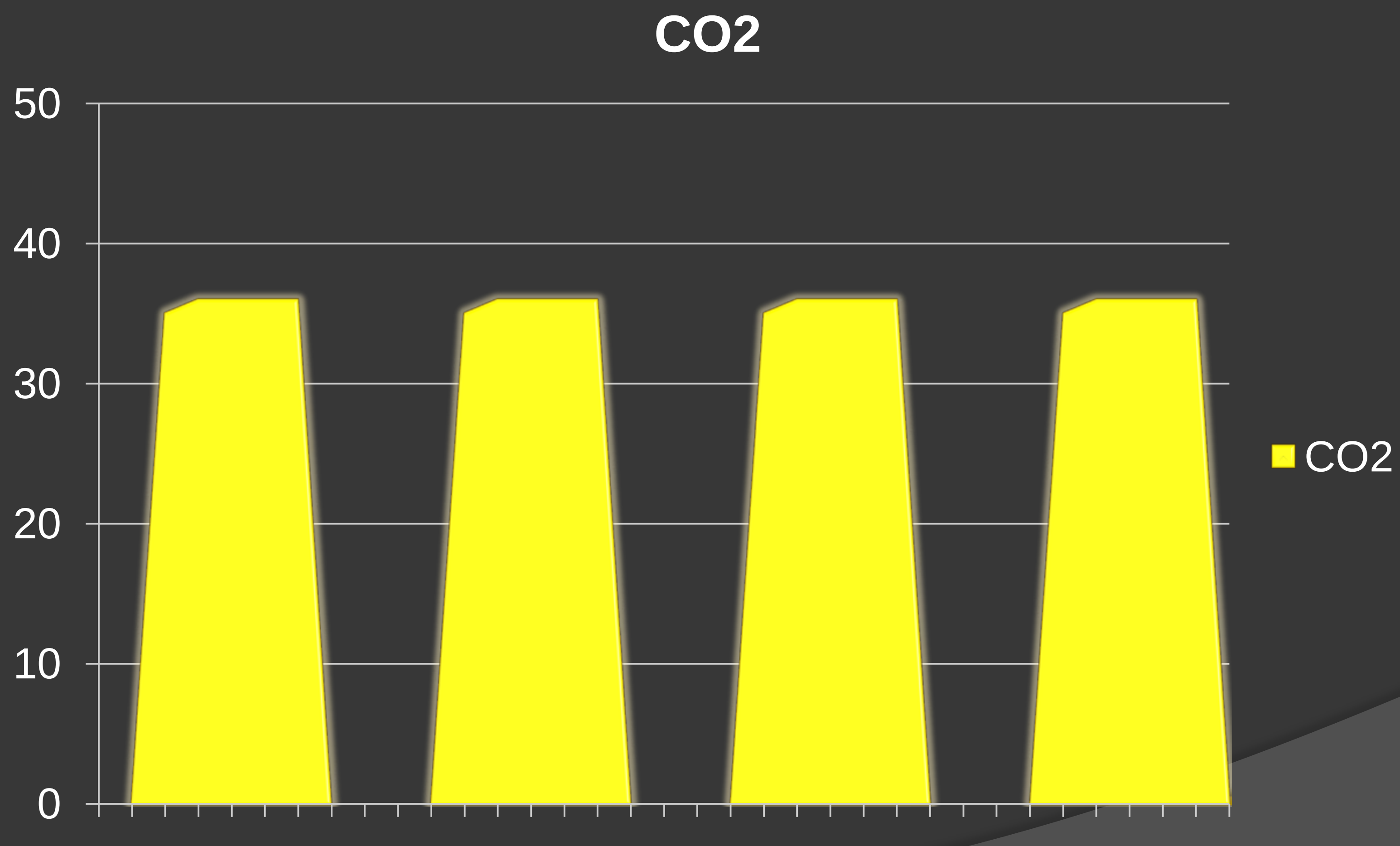
- 21 year old female
- Witnesses cardiac arrest on athletic track, defibrillated by AED
- BLS and ALS procedures per protocol
- No pulses or vitals



Case 5 Initial: No pulses



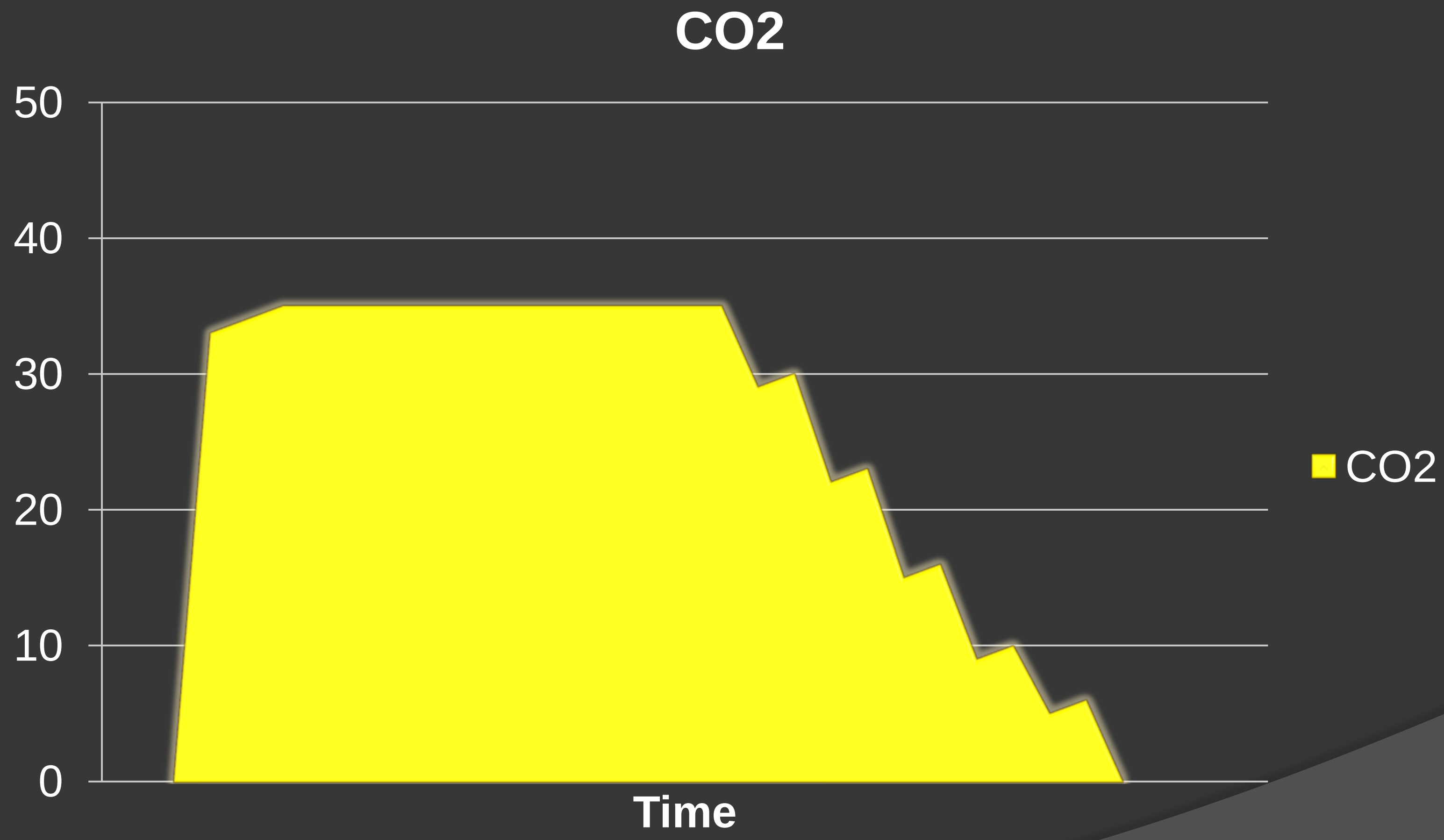
Case 5: No pulses



Cardiac Arrest and CO2

- In cardiopulmonary arrest
  - CO2 levels in blood stream increase
  - Exhaled CO2 levels decrease due to low flow states
    - No ventilation, no circulation of blood
    - No perfusion
  - Cambridge journal Article
- Return of Spontaneous Circulation (ROSC)
  - ***Spike in EtCO2 after trend of low levels***

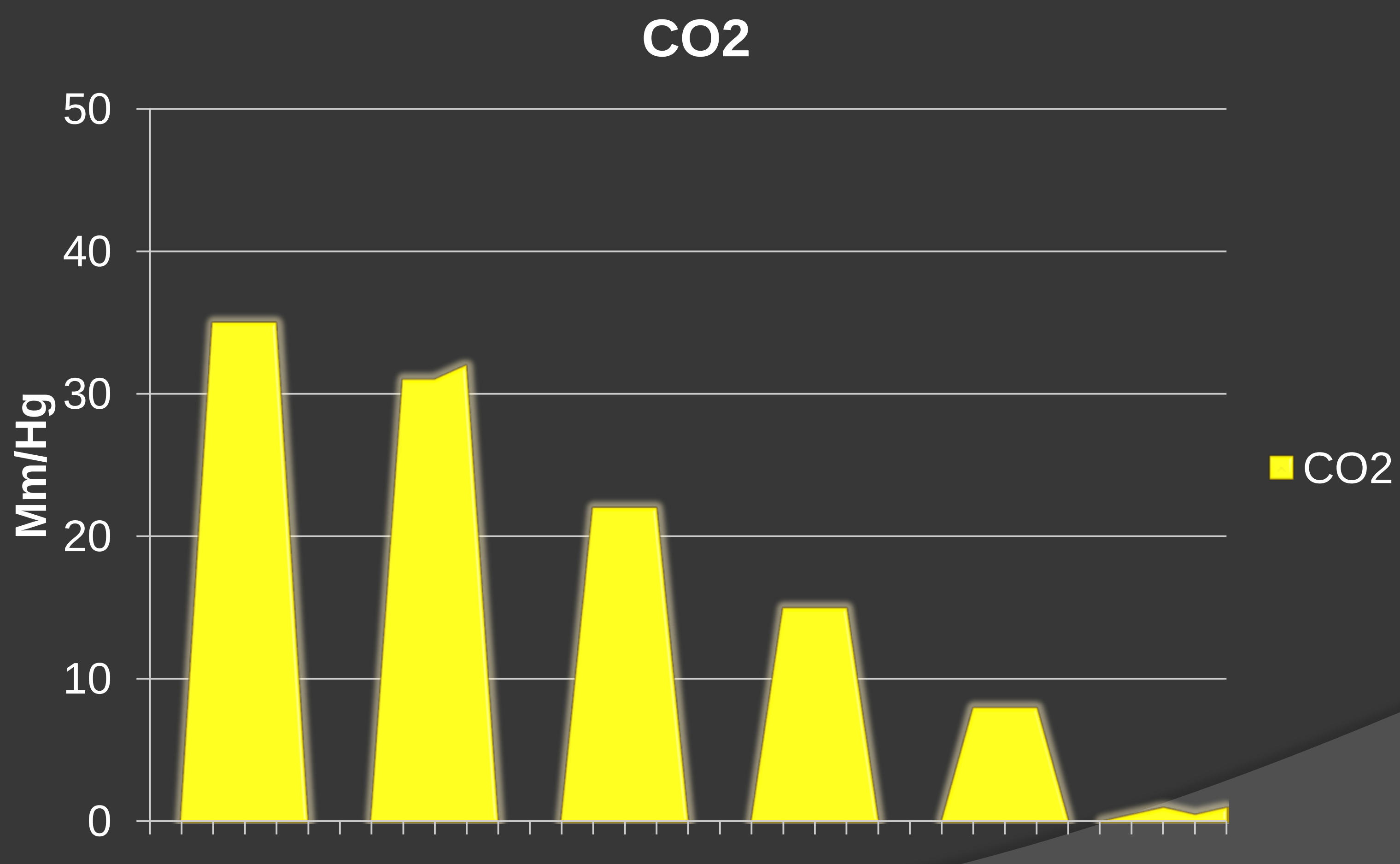
Case 5 Variant



Case 6

- 48 year old COPD
- Cyanotic, lethargic
- Vitals: HR: 131 A-fib, BP: 158/100, RR: 32, SaO_2 on NRB: 90%
- Previous Intubations for same
- Airway Considerations?
- Attempt Intubation…

Case 6



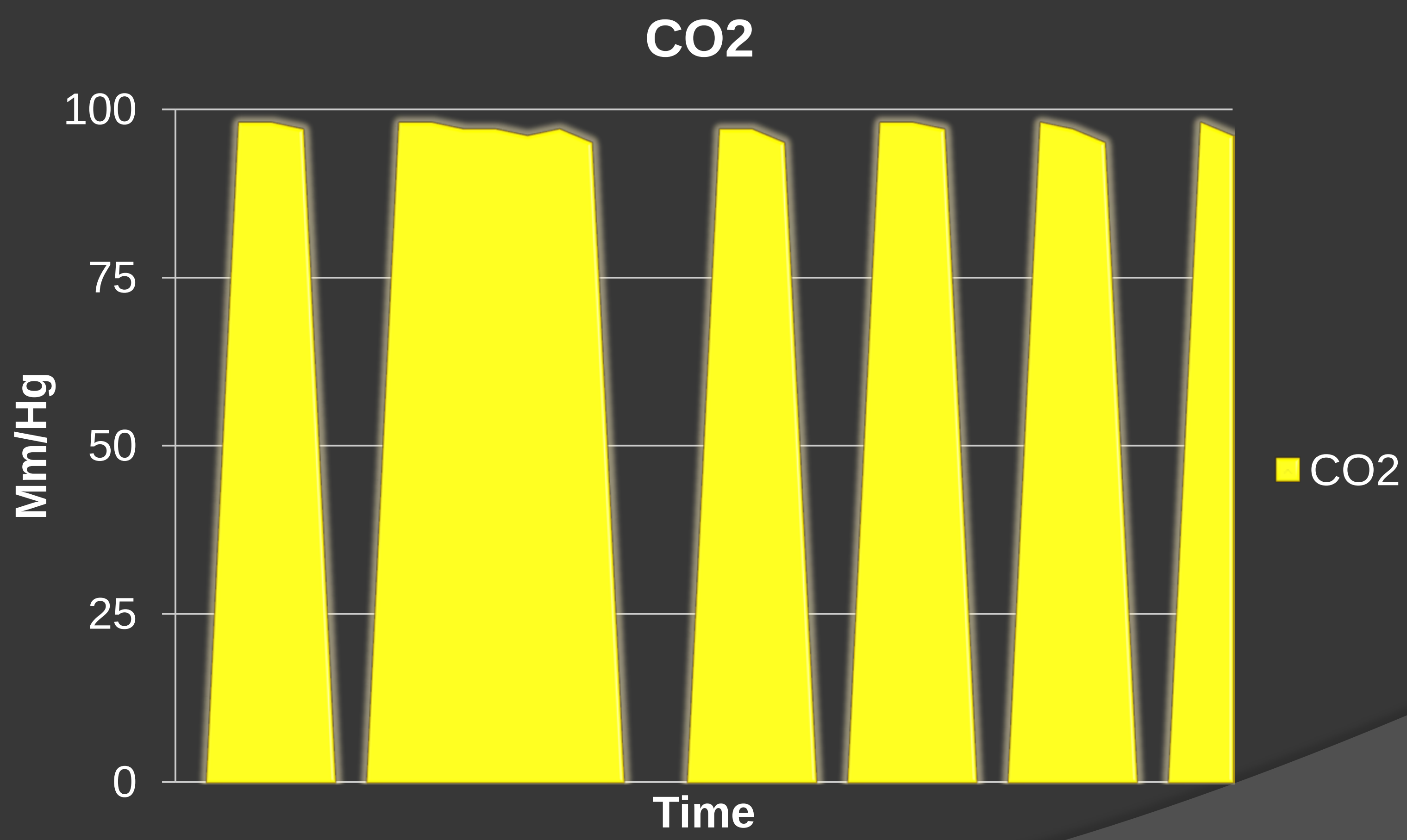
Case 7

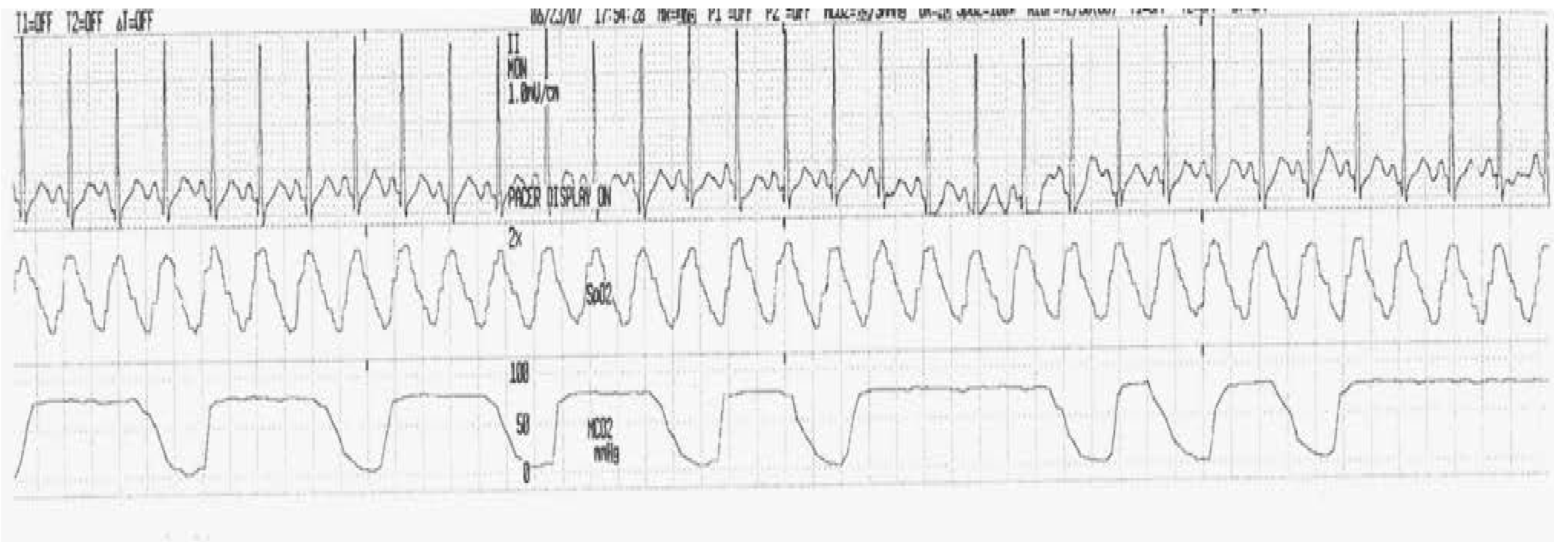
- 2 year old female with new onset seizures
- Inter-facility transport for tertiary care
- Intubated / Ventilated by BVM
  - 4.5 ET uncuffed
- Vitals: HR 160, BP 84/40, Ventilated at rate of 36, SaO_2 100%, Temp: 103
- Ventilator: FiO_2 100%, PEEP 5, initial I:E 1:2.7

Case 7

- Capnography
  - Initial level: 98mm/Hg
  - Shape: elevated box shape, irregular respiratory pattern at rate of 36
- What are your actions?
  - Increase rate?
  - Change I:E ratio?
  - ET problem
- How might etiology change treatment?
  - Asthma
  - Trauma

Case 7



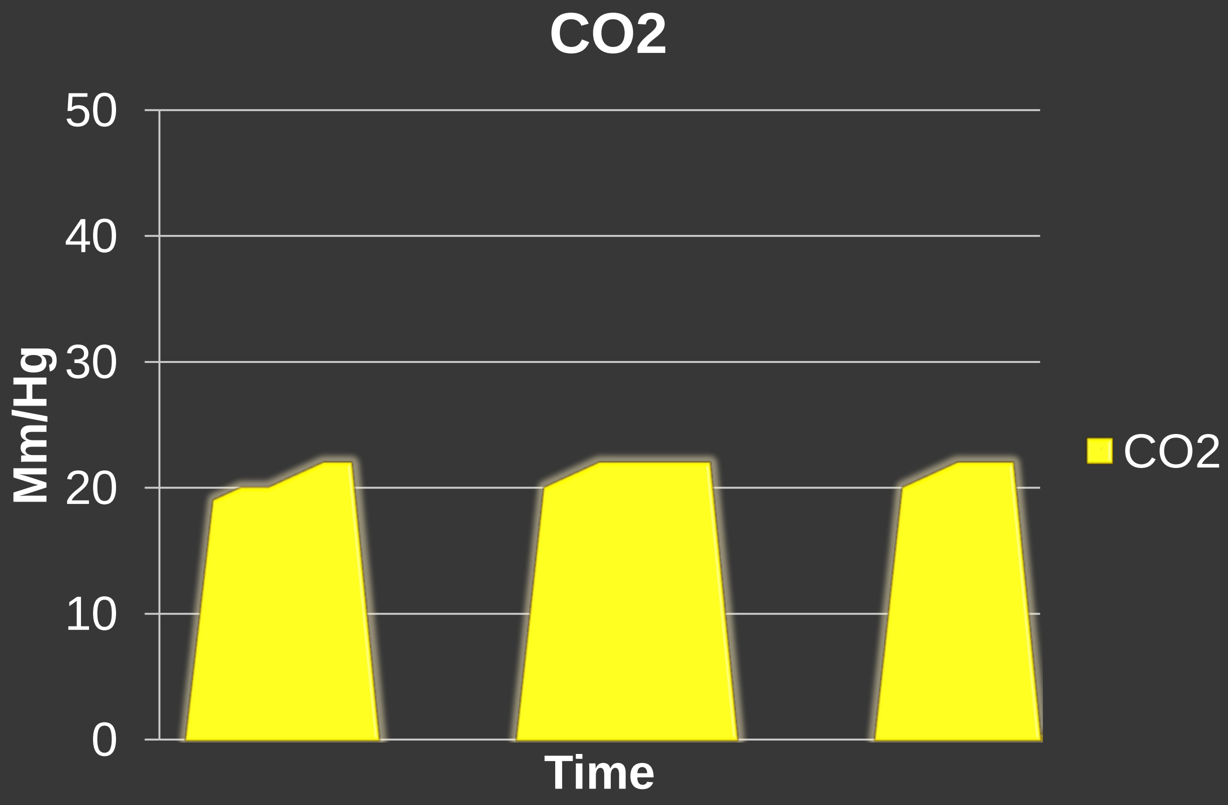


T1=OFF T2=OFF ΔT=OFF
II
MON
1.0mV/cm
PACER DISPLAY ON
2x
100
50
0
mmHg

Case 8

- Interfacility transport:
  - 56 year old male admitted with “fever”
  - Diagnosed with “sepsis:
- PMH: ESRD, IDDM, CAD, CHF
- Lethargic, GCS 12,
- Vitals: 84/60. HR 130, respirations 10 irregular
- Intubated electively for transport
- Initial EtCO2: 21mmg/Hg

Case 8



Case 8

- Capnography:
  - Reason for Low $EtCO_2$?
- What are your corrective actions?
  - Decrease ventilation rate?
  - Fluids?
  - Pressors?
  - Blood products?

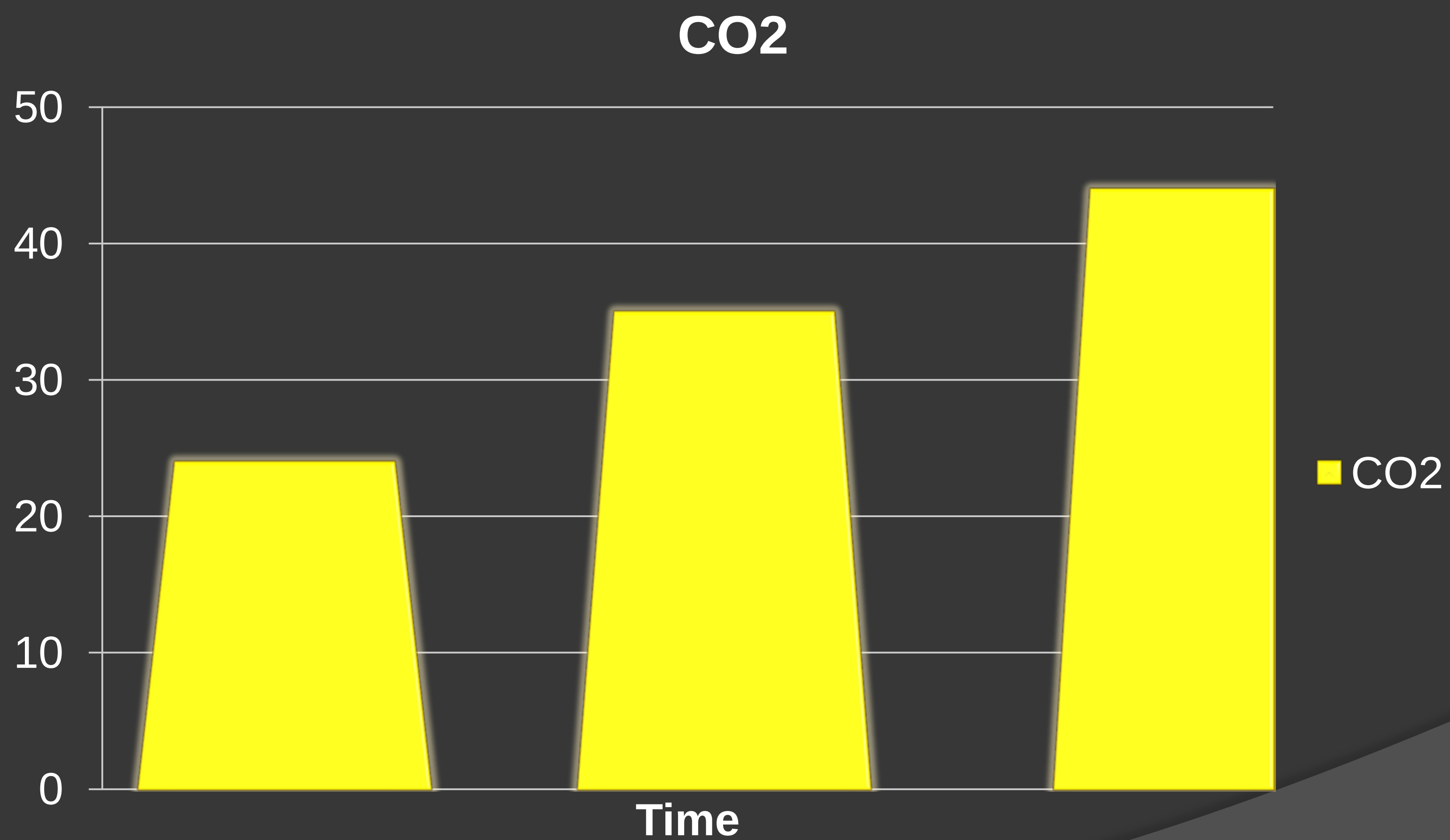
Case 8

- Consider:
  - BP of 140/90, HR 110, RR 28
- EtCO2 of 28mHg
- Respiratory alkalosis as an initial compensation for metabolic acidosis
  - Capnography considered a potential triage tool.

Case 9

- Male patient with arm trapped in roller press
- Awake, oriented, agitated and in severe pain, 10/10
  - BP 150/70, HR 118, R 20, SaO_2 100%
- Movement of arm increases agitation and reduces access
- Movement of rollers causes pain
- Elect to sedate for extrication
  - Online medical control

Case 9



Case 9

- Need for pain control and sedation
- Patient is in difficult position to monitor vitals
- What is your pain control protocol?
- Do you have a sedation protocol?
- How much is too much?
  - Capnography by sidestream

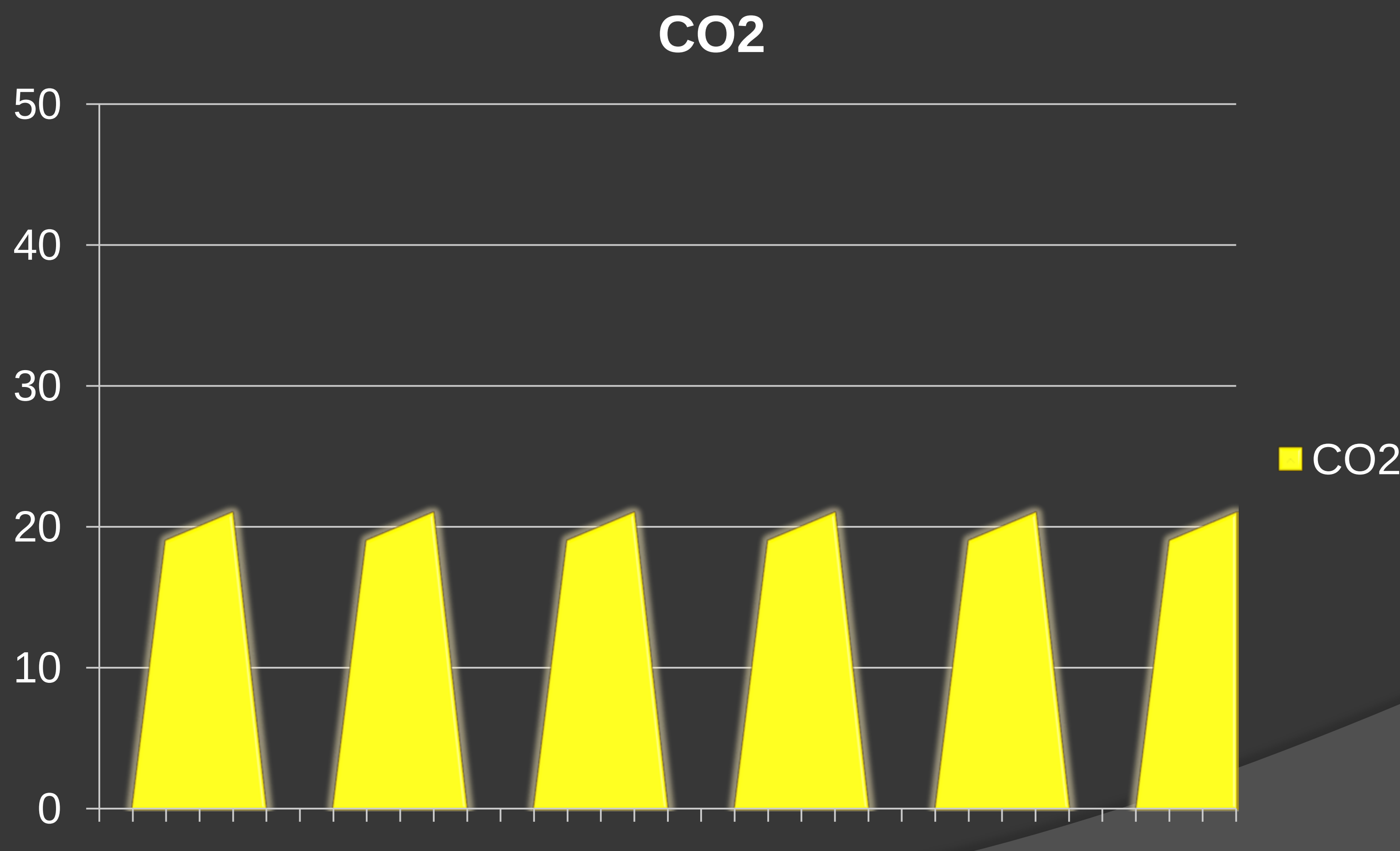
Case 9: Sedation

- Quality of ventilation
- Detection of Apnea
- Predictor of Compromise
- Out-of Hospital sedation:
  - Long distance and air medical transport
  - Extrication

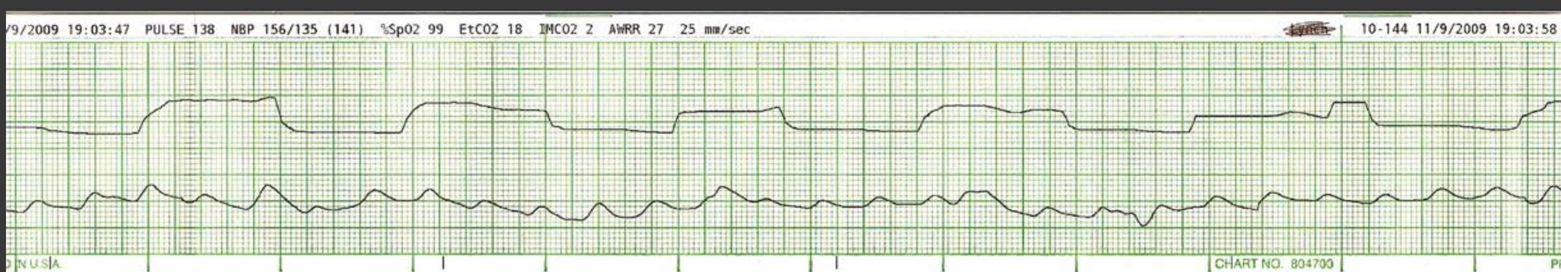
Case 10

- 21 year old male c/c chest pains
- Sudden onset
- Stabbing, non-radiating, 10/10
- Tingling in his fingers

Case 10

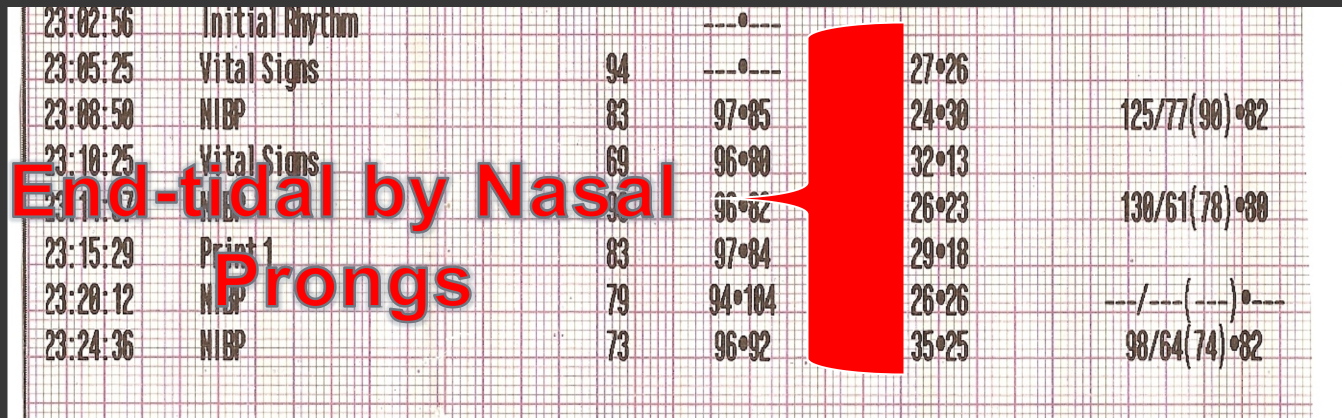


Varient

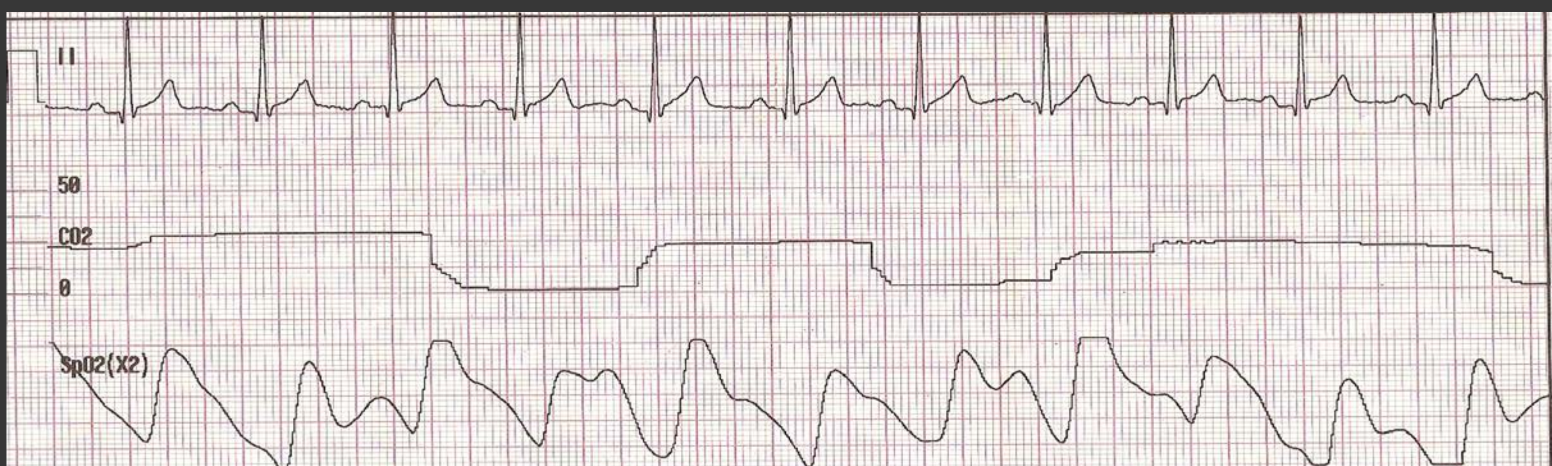


/9/2009 19:03:47 PULSE 138 NBP 156/135 (141) %SpO2 99 EtCO2 18 IMCO2 2 AWRR 27 25 mm/sec
10-144 11/9/2009 19:03:58
CHART NO. 804700

Case 10



23:02:56 Initial Rhythm ---•---
23:05:25 Vital Signs 94 ---•--- 27•26
23:08:50 NIBP 83 97•85 24•30 125/77(90)•82
23:10:25 Vital Signs 69 96•80 32•13
26•23 130/61(78)•80
23:15:29 83 97•84 29•18
23:20:12 79 94•104 26•26 ---/---(---)•---
23:24:36 NIBP 73 96•92 35•25 98/64(74)•82
End-tidal by Nasal Prongs

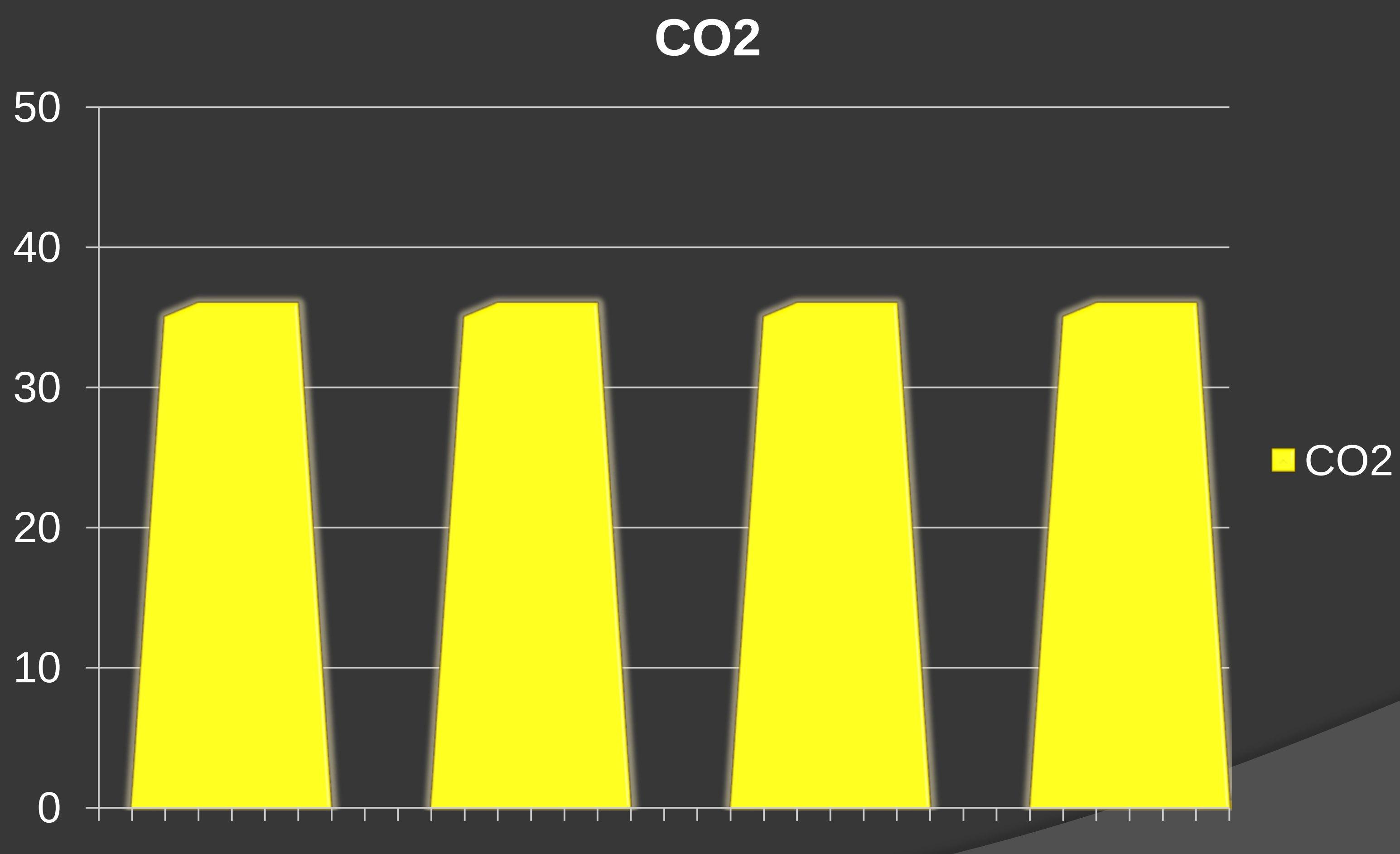


II
50
CO2
0
SpO2(X2)

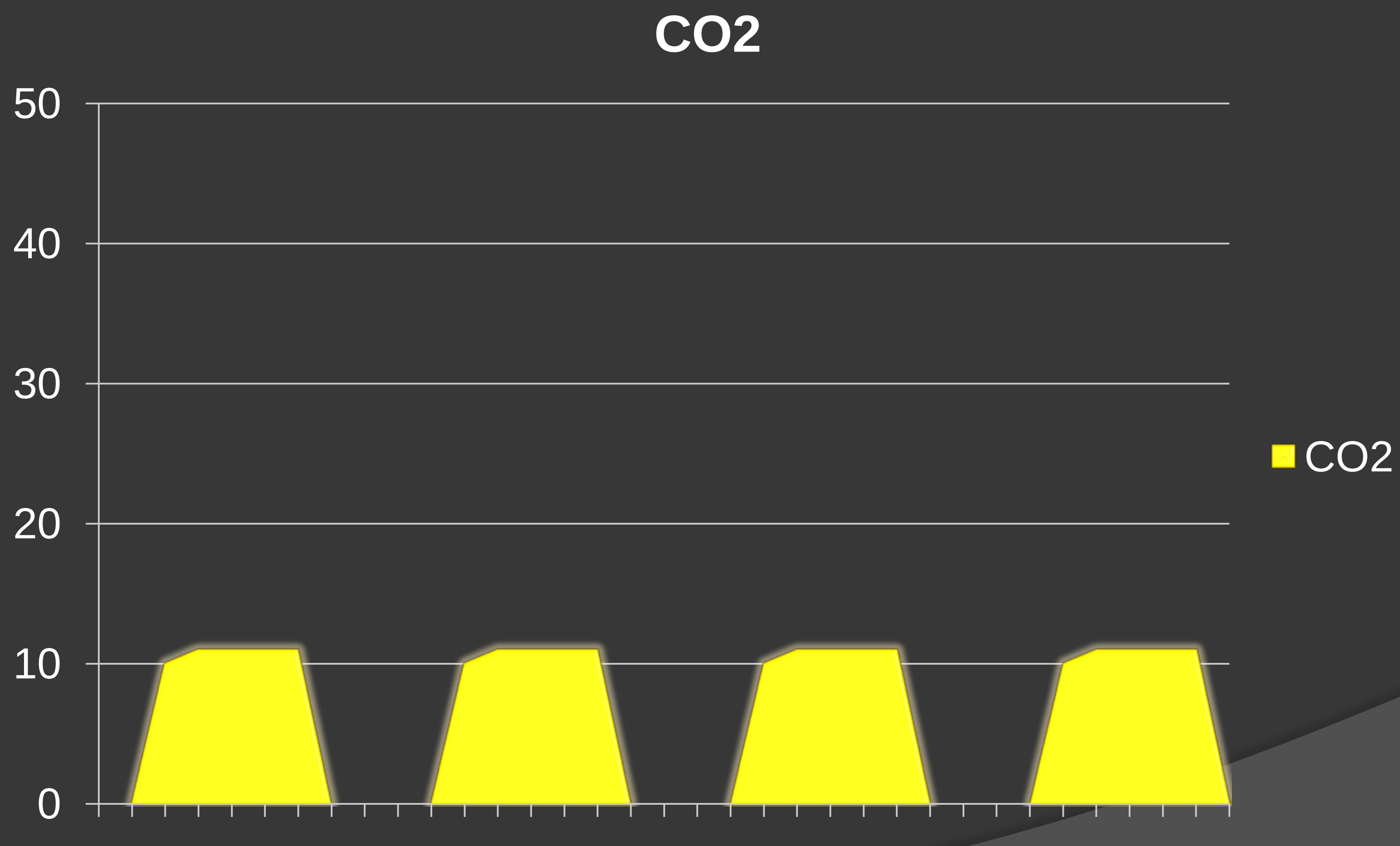
Case 11

- Female trauma patient
  - Unrestrained driver with steering wheel deformity; found under dash after airbag deployed
  - Pattern of injury??
- Intubated successfully
  - Confirmed by waveform sedated and paralyzed
- 25 minute flight to Trauma Center

Case 11: Cruising Along



Case 11: Sudden Change!



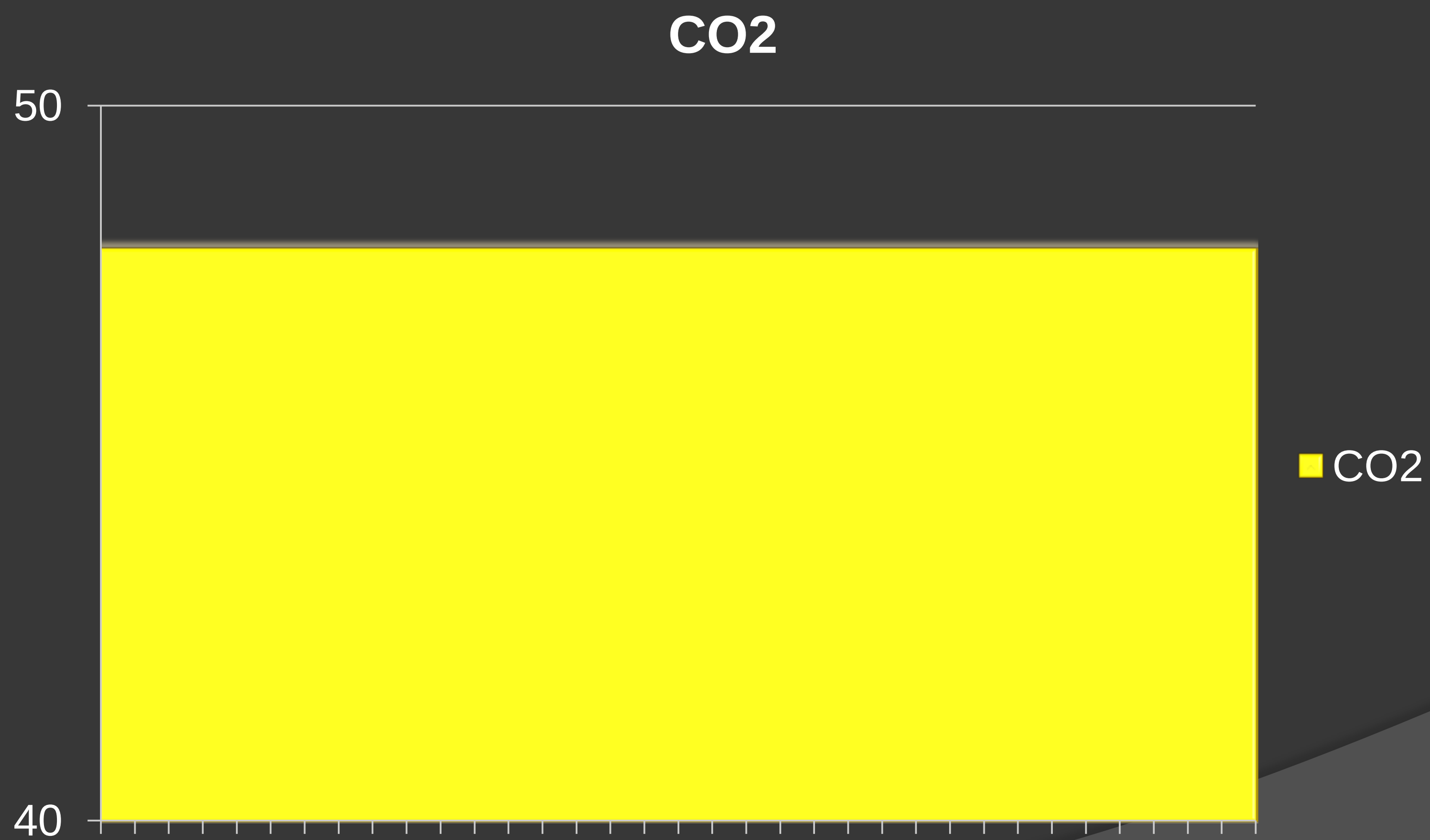
Case 12

- 57 year old obese male with spinal trauma
  - Fell forward, hyper-flexion of neck
  - Confirmed C5, C6 fractures
- CNS Intact-full movement
  - GCS of 9T (14 if not intubated)
- Intubated: and we did not know how
  - Sedation/fiberoptic ETI by anesthesia
- On T-piece, NOT VENTILATED breathing on his own

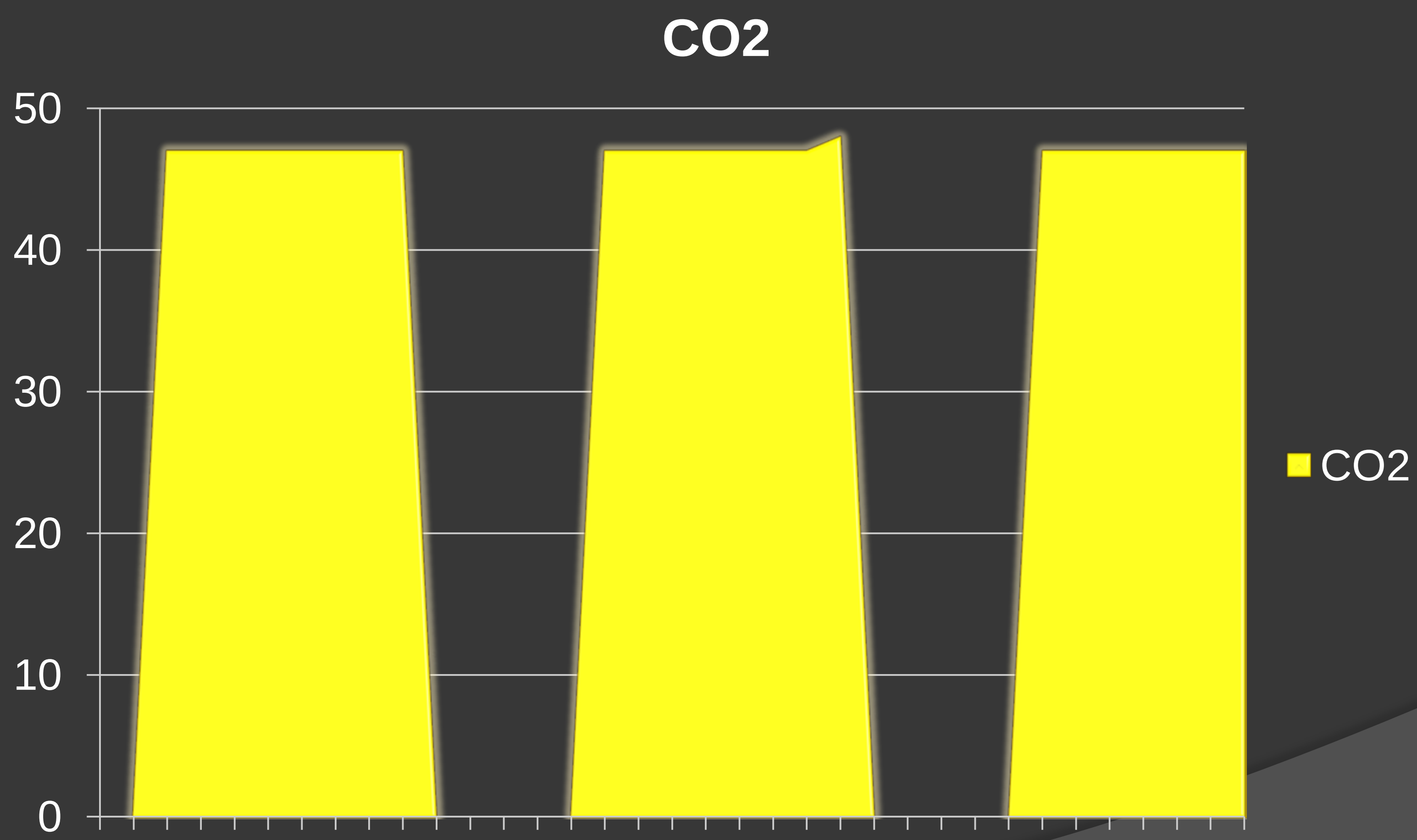
Case 12

- Considerations:
  - Community hospital to Level 1 trauma Center
  - Patient obese: 280 pounds
  - Aircraft: EC135
  - No existing ventilator settings; crew discretion on “optimal”
  - Difficult airway on multiple dimensions
    - Confirmed by CXR prior to movement

Case 12: Volume Ventilation



Case 12: Pressure Ventilation



Case 12

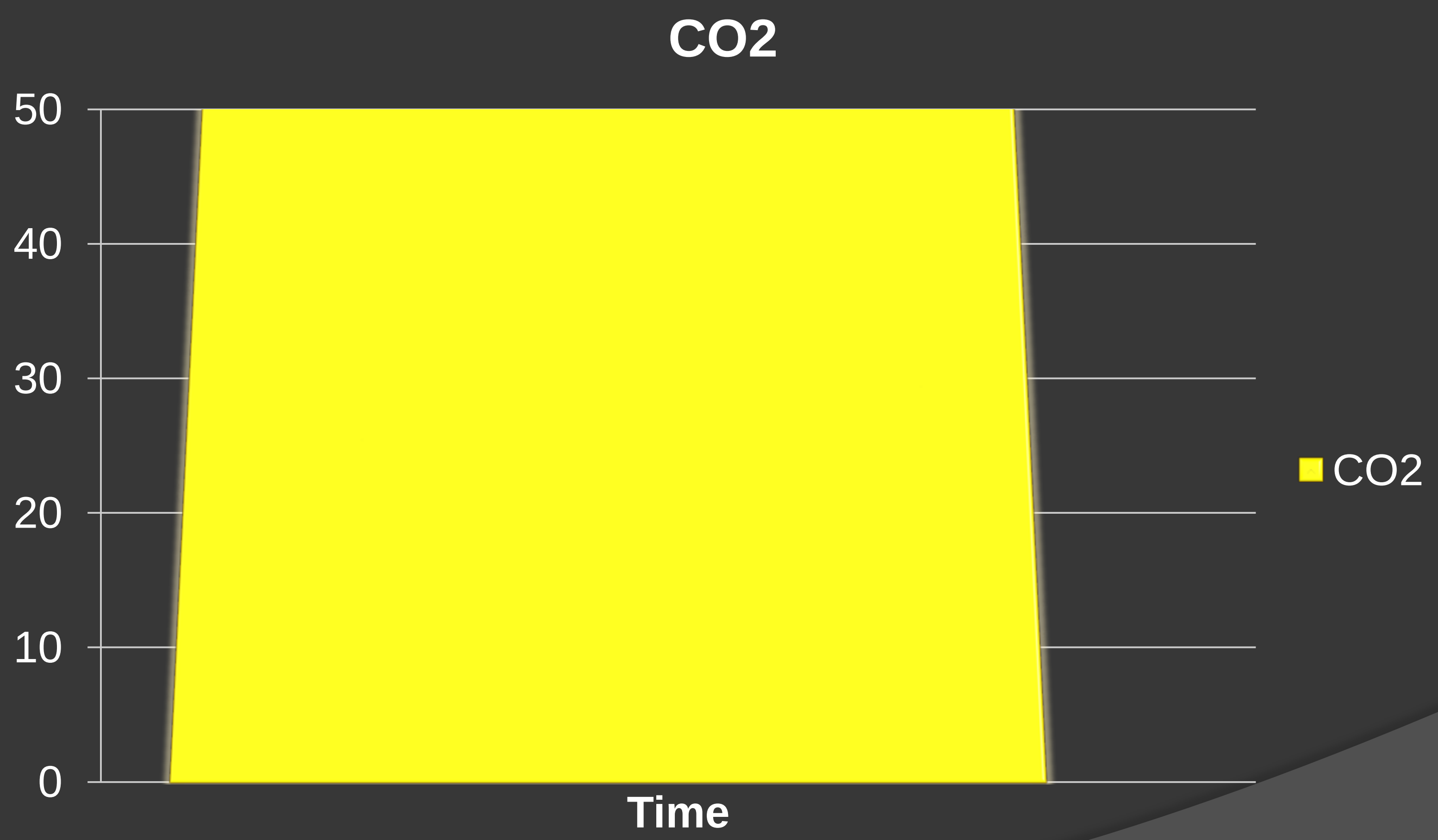
- Pressure versus volume ventilation
  - Pressure Control 24, FiO_2 100%, Rate 12, Assist Control with PSV
  - Switch to BVM after desaturation
- Sedation, paralysis, pain control
- How might a different airframe change management? Or ground unit?
  - Bell 407 vs. 412
  - EC130 vs EC 135/145

Case 12

- Physical restriction of breathing
  - Burns
  - COPD
  - Trauma
  - Surgical

Case 13

- 24 y/o patient in head on MVC
- Altered LOC, combative, signs of head injury
- RSI clinical course
  - Etomidate 0.3 mg/kg
  - Succinylcholine 1.5 mg/kg
- After paralytic, patient developed trismus and rigidity
- Unable to intubate, but can ventilate with oral airway in place
  - Unable to open mouth, to place King LtD


CO2
50
40
30
20
10
0
Time
CO2

Case 13 Malignant Hyperthermia

- Life Threatening
- Hypermetabolic state in patient's with hereditary skeletal muscle defect
  - Genetic predisposition 1:10000
  - Clinical Incidence 1:30000
- Depolarizing muscle relaxants (Succinylcholine) and anesthetic gases cause raise in myoplastic calcium

Malignant Hyperthermia: Signs and Symptoms

- Hypercarbia: most sensitive indicator in intubated patient
- Tachycardia
- Tachypnea
- Temperature elevation
- Hypertension
- Dysrhythmias
- Acidosis
- Hypoxia
- Hyperkalemia
- Skeletal muscle rigidity
- Myoglobinuria

MH Management

- Get help: Medical control
- Hyperventilate patient with 100% oxygen
- Cool patient
- Antidote is Dantrolene
  - Truly the only effective treatment
  - Operating rooms have an MH cart stocked with multiple bottles
- Prehospital considerations
  - Non-depolarizing paralytic
  - Benzodiazepines

Critical Care Transport

- Verification of ETI, as with scene
- Evaluation of ventilation
  - Alter ventilator settings
- Evaluation tool for perfusion
- Simple information will help reflect in large changes
  - Decrease ventilation rate
  - Improve quality of chest compressions

Transition Monitoring

- Specific to non-cardiac, trauma patients
- Handheld device in pouch: combine EtCO2 and SaO2
- Advantages:
  - Reduces scene and movement times
  - Provides critical but NOT complete information
  - Reduces bulk

Summary:

- Capnography is a TOOL
  - Does not substitute for good clinical skills
- Remember the BASICS
  - ABCs
- DO NOT OVERTHINK Capnography
  - Some cases will be difficult to figure out

Sources:

Ahrens, T. D., & Sona, C. M. (2003). Capnography Application in Acute and Critical Care. *AACN Clinical Issues , 14* (2), 123-132.

American Society of Anesthesiologists. (2005, October 25). *Publications and Services*. Retrieved September 16, 2007, from American Society of Anesthesiologists: http://www.asahq.org/publicationsAndServices/sgstoc.htm

Brain Trauma Foundation. (2000). *Guidelines for Prehospital Treatment of Traumatic Brain Injury.* New York: Brain Trauma Foundation.

Cooper, J. B. *Medical Technology: Patient Safety is Paramount.*

Garey, B. (2007, August 18). Flight Paramedic, Medflight I. (M. Watkins, Interviewer)

Gravenstein, J. S., Jaffe, M. B., & Paulus, D. A. (2004). *Capnography.* Cambridge, United Kingdom: Cambridge University Press.

Hassett, P., & Laffey, J. G. (2007). Permissive Hypercarbia: Balancing Risks and Benefits in the peripheral microcirculation. *Critical Care Medicine* , 2229-2230.

Huether, S. E., & McCance, K. L. (2004). *Understanding Pathophysiology* (3 ed.). St. Louis, Missouri: Mosby Elsevier.

Hutchison, R., & Rodriguez, L. (2008). Capnography and Respiratory Depression. *American Journal of Nursing , 108* (2), 35-39.

McGillicuddy, D., Tang, A., Cataldo, L., Gusev, J., & Shapiro, N. I. (2008). Evaluation of end-tidal carbon dioxide role in predicting elevated. *Intern Emergency Medicine* , pre-publish.

THANK YOU!!!!

ANY QUESTIONS?