Capnography?
But My Patient Isn't Tubed!

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Full Disclosure

- I am a paid consultant for Oridion Capnography, Inc
- This talk is sponsored by Oridion

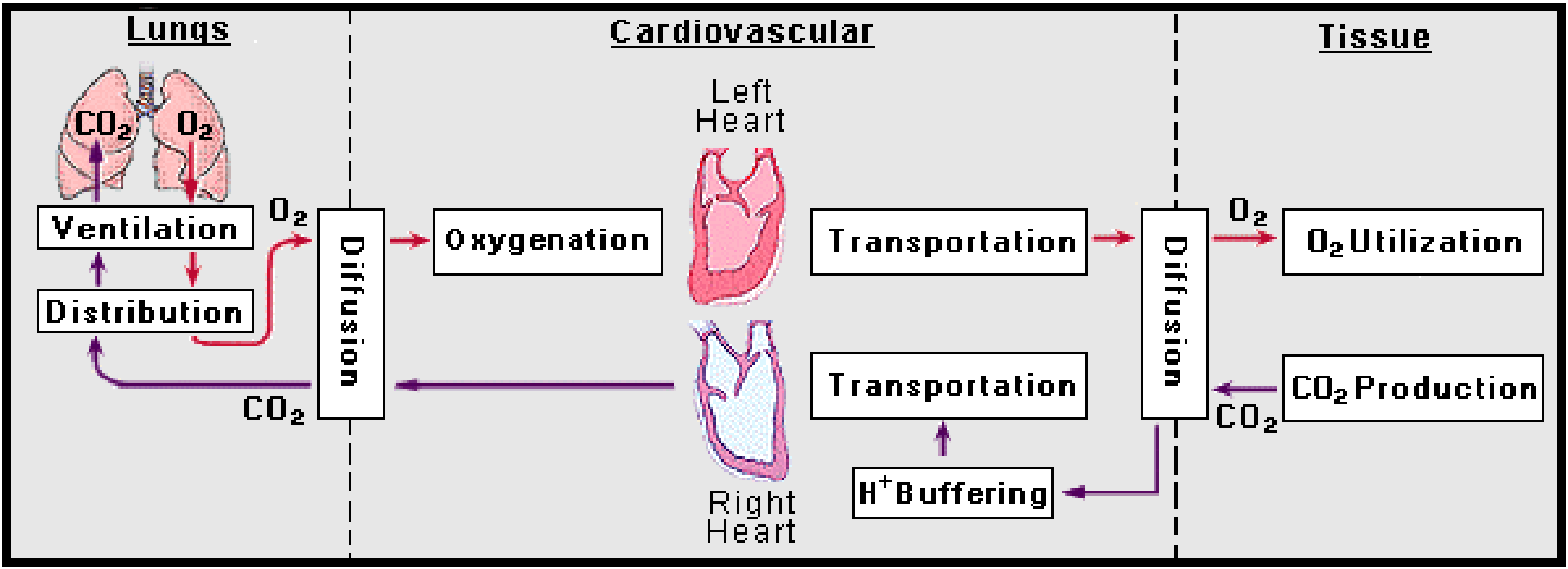
Oridion®

Smart Solutions One Breath at a Time™

A Brief History

- 1630, Flemish scientist Jan Baptista van Helmont found burning wood gave off a gas (wood gas)
- 1750's, Scottish chemist Joseph Black discovered CO_2 (fixed air) after heating magnesium carbonate
- 1865 John Tyndall reported his experiments using IR absorption to measure CO_2 in exhaled breath (calculated to be 4.5-5%)
- 1939, August Herman Pfund developed a respiratory gas analyzer used at Johns Hopkins Hospital
- 1950's capnography became commercially available (decreased mortality during polio epidemic)
- Continuing research has identified many issues associated with and uses of capnography
- Capnography has become standard of care in many situations (tracheal intubation, anesthesia, monitoring RR)

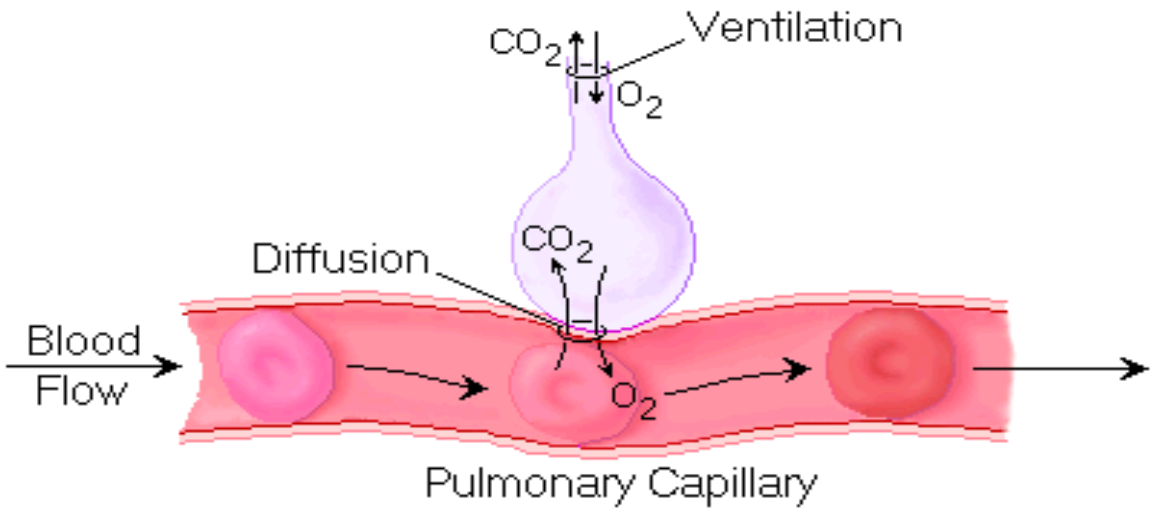
Functional Process of Respiration



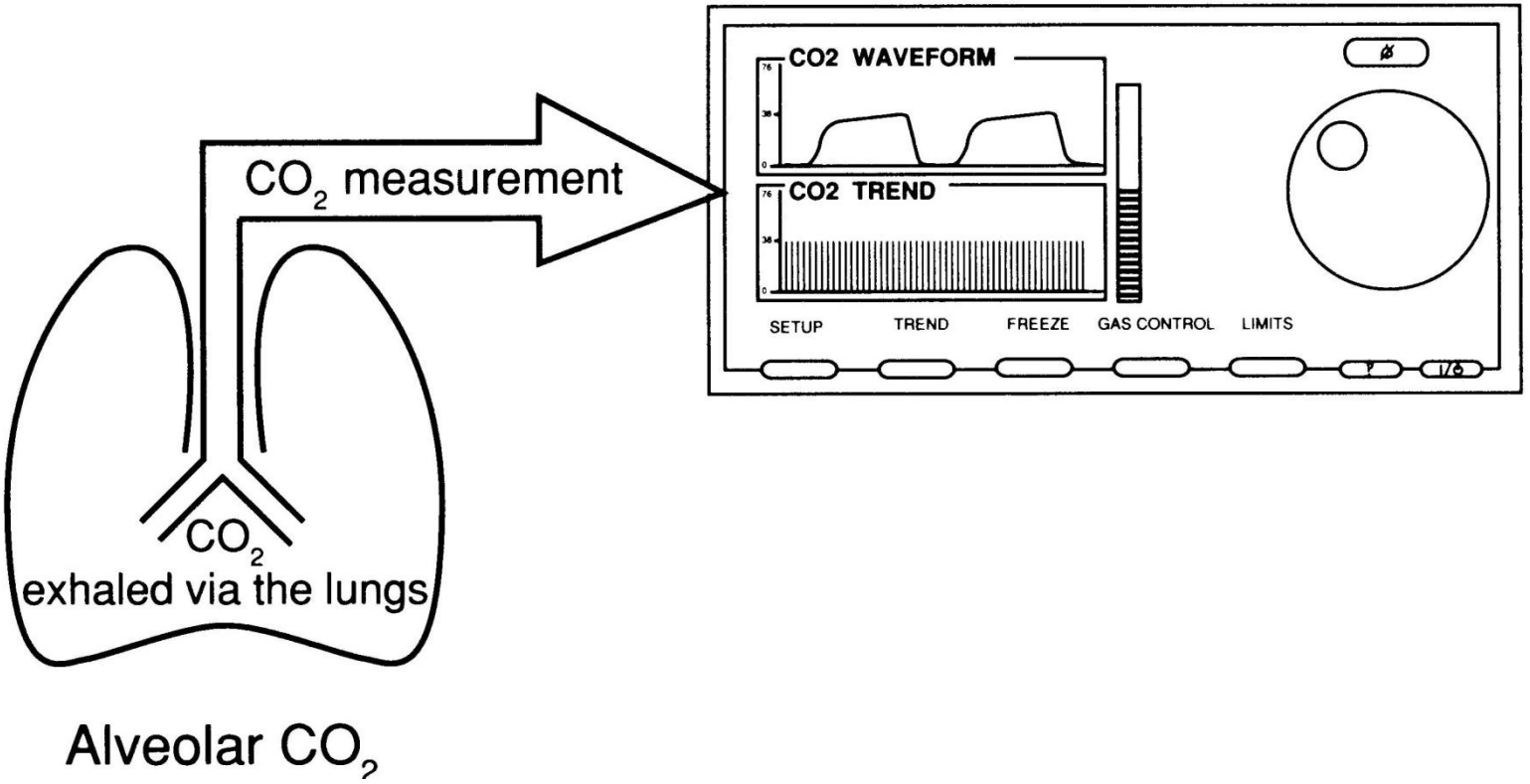
Note: Ventilation and Oxygenation are separate, but related, processes

Determinants of Alveolar Gas Composition

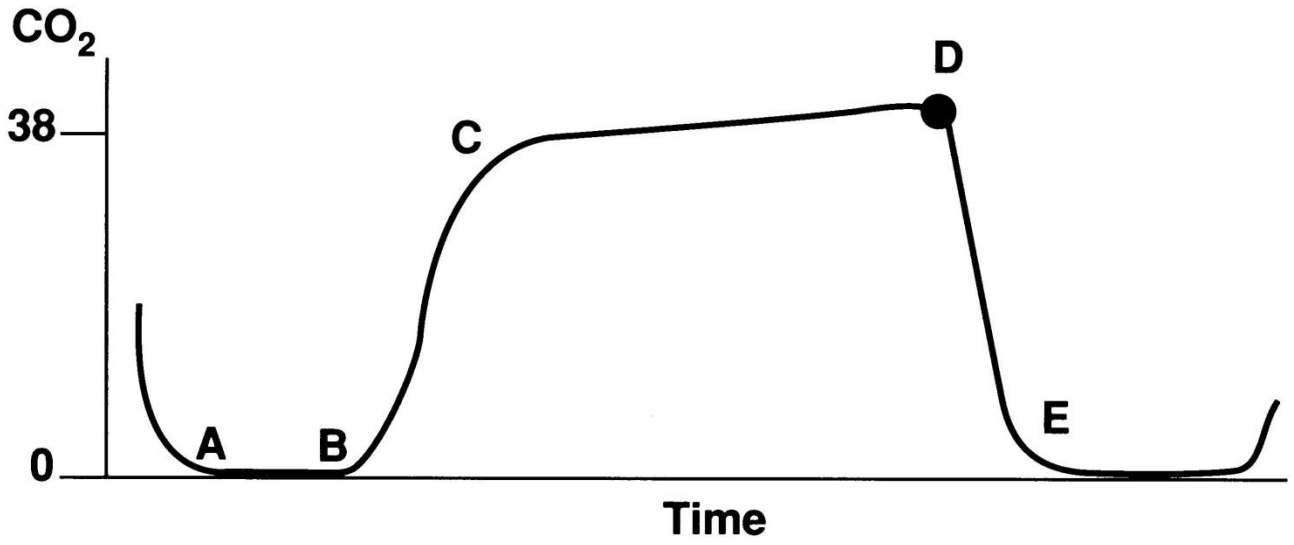
1. The quantity and quality of gases delivered to and from the alveoli by **ventilation**
2. The **diffusion** rate of gases between the alveoli and pulmonary capillary blood.
3. The cardiac output or **blood flow** through pulmonary capillaries which removes O_2 and adds CO_2 to alveoli.



Capnography



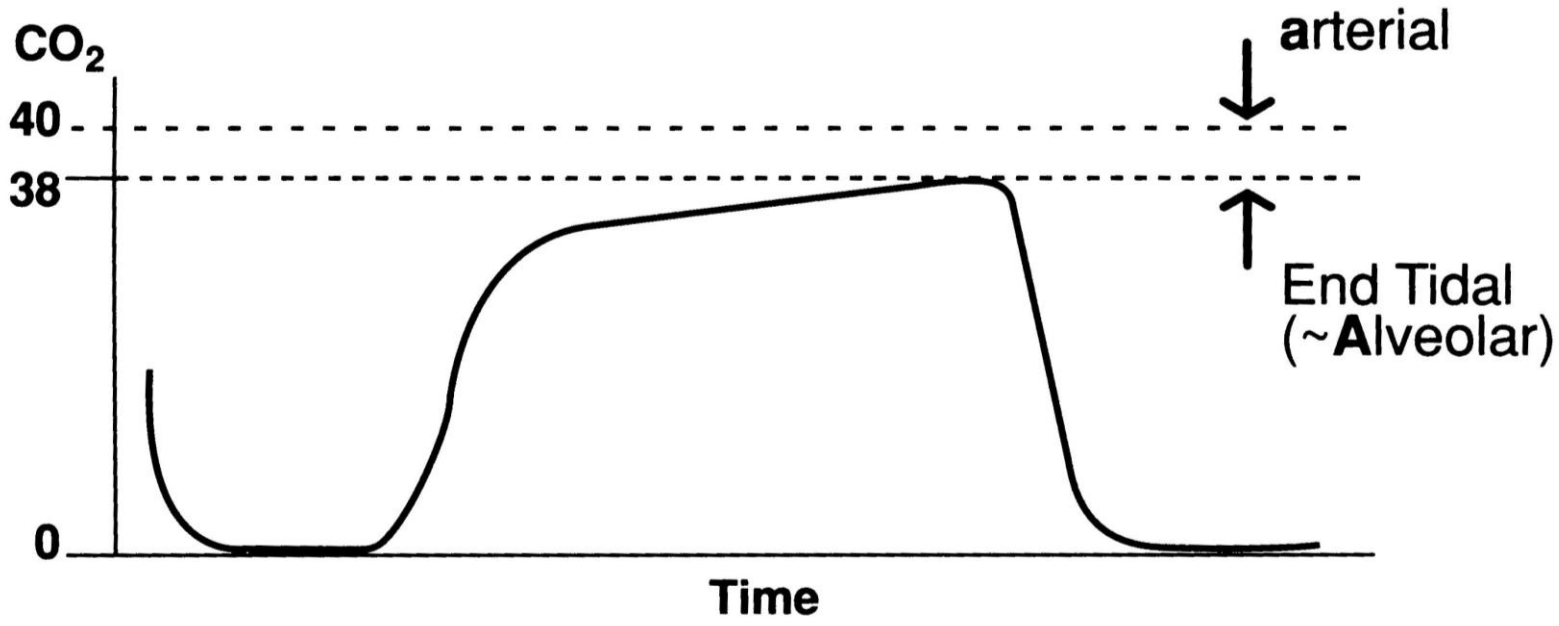
Normal Capnograph



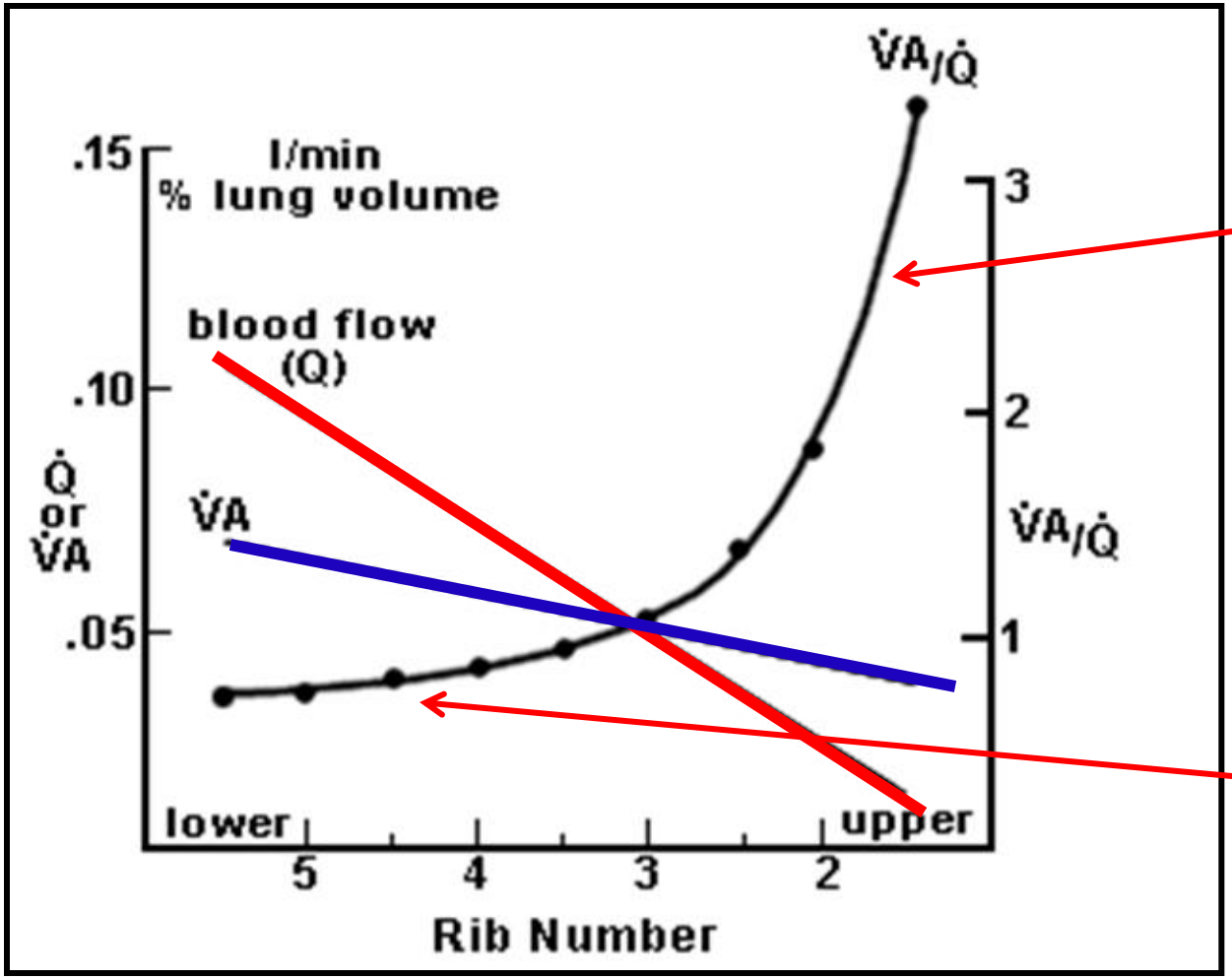
- Zero baseline (A-B)
- Rapid, sharp rise (B-C)
- Alveolar plateau (C-D)
- End-tidal value (D)
- Rapid, sharp downstroke (D-E)

$PaCO_2$ vs. $P_{ET}CO_2$

Normal a-$ADCO_2$ = 2-3 mmHg



Ventilation/Perfusion (V/Q) Matching: Effect on P_ACO2



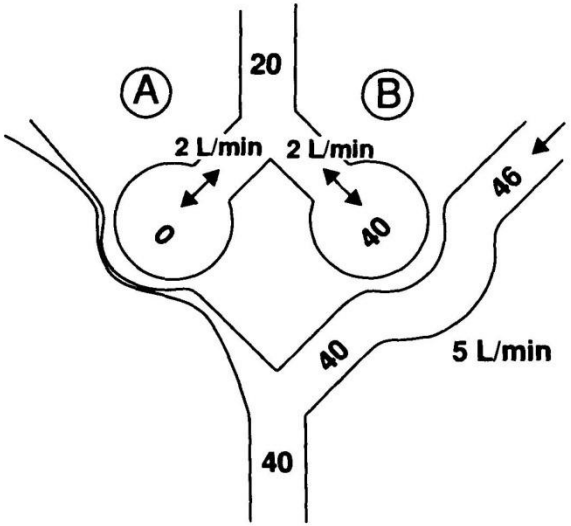
Lower P_ACO_2

Higher P_ACO_2

Causes of Increased a-$ADCO_2$

- Poor sampling technique/equipment failure
- Ventilation/perfusion mismatch
  - Dead space ventilation
  - Shunt perfusion
- Incomplete alveolar emptying

V/Q Mismatch: Effects on a-$ADCO_2$



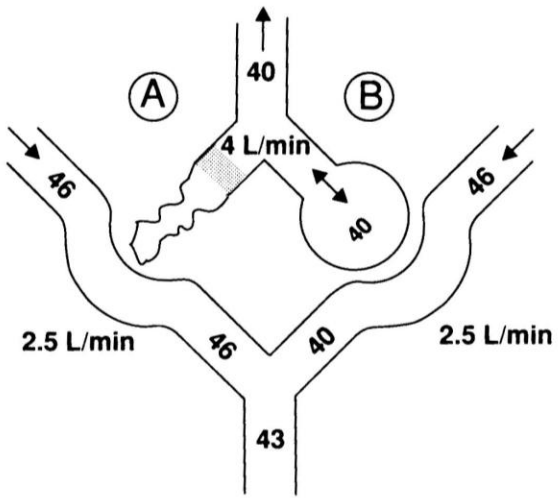
Lung 'A' is ventilated but not perfused

(a-$ADCO_2$ = 20 mmHg)

Conditions with dead space ventilation:
(can result in a large difference between arterial and end-tidal CO_2value (a-$ADCO_2$))

- Lateral decubitus position
- Pulmonary hypoperfusion
- Air embolism
- Pulmonary thromboembolism
- Cardiac arrest

V/Q Mismatch: Effects on a-$ADCO_2$



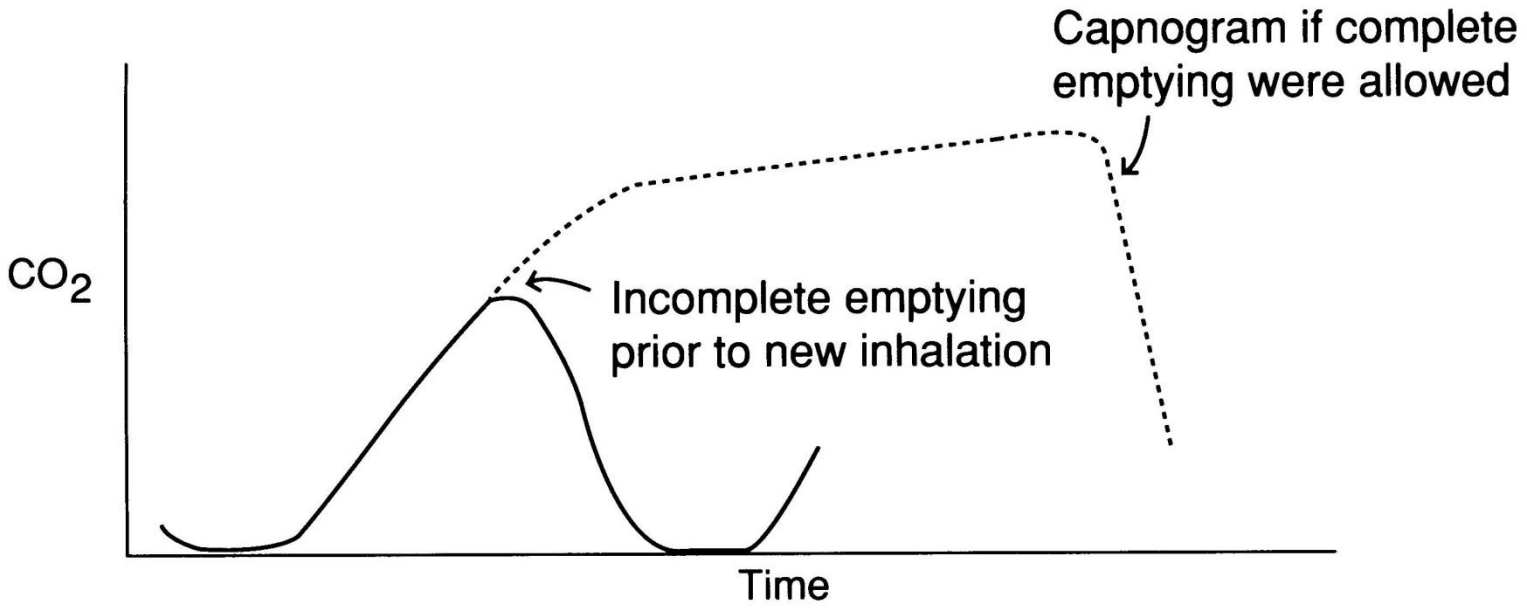
Ventilation to lung 'A' is interrupted but blood flow is normal

(a-$ADCO_2$ = 3 mmHg)

Conditions with shunt perfusion:
(can result in little or no arterial to end-tidal difference)

- Atelectasis
- Pneumonia
- Mucus Plugging
- Bronchial intubation

Incomplete Alveolar Emptying



Conditions which cause incomplete alveolar emptying:

- COPD
- Asthma
- Upper airway obstruction
- Partial endotracheal tube obstruction

Capnography Methods

- Infrared absorption
- Mass spectrometry
- Raman spectroscopy

Mainstream vs. Sidestream

Mainstream

- No gas removed from circuit
- Mechanical deadspace
- Sensor has weight
- Sensor may be damaged or lost
- Waveform in real time
- Difficult to adapt to non-intubed patients

Sidestream

- Gas removed from circuit
- Minimal deadspace
- Light adapter
- Sampling line may clog
- Waveform is delayed
- Easily adapted for non-intubated patients

Respiratory Monitoring

- ECG
- Pulse oximetry
- Electrical impedance
- Impedance pneumography
- Capnography

Clinical Uses for Capnography

- Monitor adequacy of ventilation
- Detect breathing/apnea
- Ventilator/circuit malfunction
- Verify placement of ETT
- Detect blocked or kinked ETT
- Detect dead space ventilation
- Identify/monitor distal airway obstruction
- Monitor neuromuscular blockade

Clinical Uses for Capnography

- Estimate cardiac output
- Detect pulmonary embolism
- Monitor adequacy of CPR
- Identify ROSC (Return of Spontaneous Circulation)
- Others

Capnography Use in Non-intubated Patients

- Monitor ventilation
  - RR
  - Obstruction (bronchospasm)
  - Apnea (OSA)
  - Hypo-/hyperventilation
- Evaluate deadspace ventilation
- Evaluate metabolic acidosis

Non-Invasive Ventilation

- Capnography can be utilized with NIV
- Interface is main issue
  - Airway opening
  - Mask port

INFLUENCE OF SAMPLING SITE ON END TIDAL CARBON DIOXIDE LEVELS ($P_{ET}CO_2$) DURING NON-INVASIVE POSITIVE PRESSURE VENTILATION (NPPV)
Taft AA, Waugh JB, and Pippin GR
Poster presentation AARC, Dec, 2009

Non-Invasive Ventilation

- 3 masks studied at three settings
- Simultaneous oro-nasal cannula monitoring

ResMed
Mirage Quatro

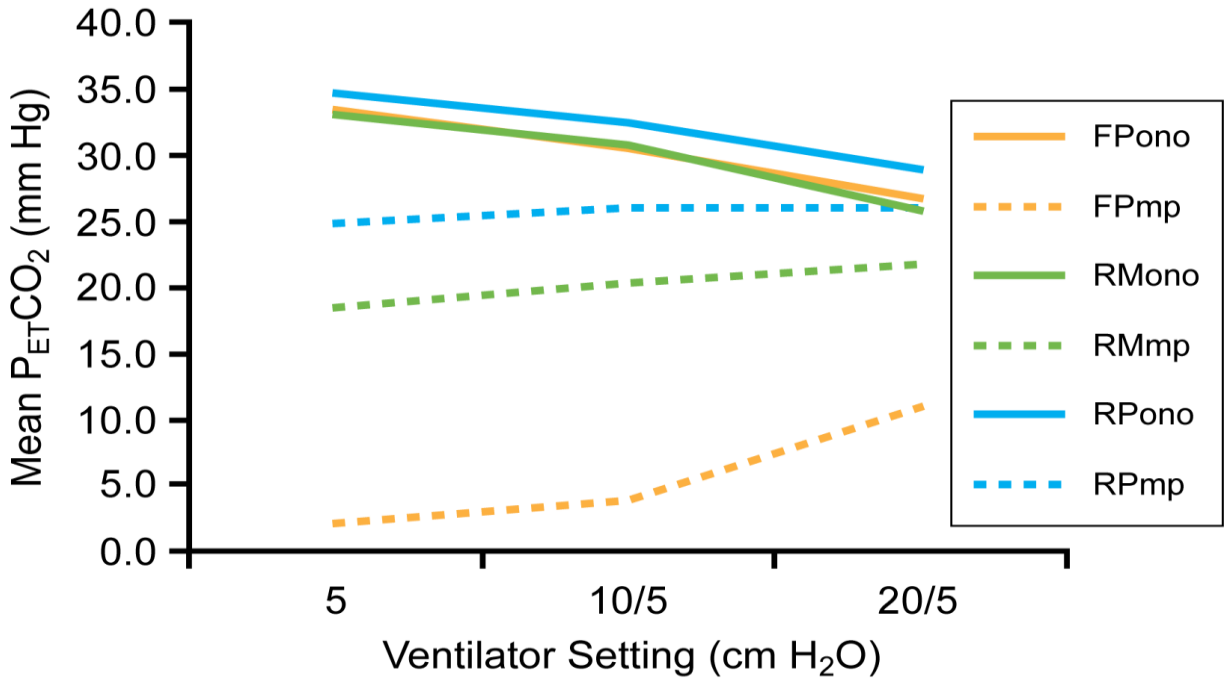
Respironics
PerformaTrak

Fisher-Paykel
Flexifit 431

Oridion
Smart Capnoline

Non-Invasive Ventilation

Effect of Mask, Ventilator Setting, and Sampling Site on $P_{ET}CO_2$



Non-Invasive Ventilation

Mask Port

- Masks give different results
- No correlation with baseline except at highest ventilator settings
- Waveform degraded
- Useful for RR monitoring if sampling port is on mask

Oro-nasal Cannula

- Results unaffected by mask type
- Correlates well with baseline at all settings
- Waveform remained distinct
- Recommended site when using capnography during NIV

Emergency Department

- Monitoring Respiratory Status
  - Seizures
  - Bronchospasm
- Identification of metabolic acidosis
  - Diabetes
  - Gastroenteritis
- Triage
  - Chemical terrorism

Resuscitation

- Changes in $P_{ET}CO_2$ are related to cardiac output
  - Constant minute ventilation
- Can be used to monitor:
  - Spontaneous return of circulation
  - Quality/effectiveness of compressions
- Predict survival
  - $P_{ET}CO_2$ levels are higher in those surviving

"You can observe a lot just by watching"

Yogi Berra

Procedural Sedation

- Depressed ventilation is common, but clinical observation of RR is inadequate
- Capnography acts as an early warning for a disasterous respiratory event
- Pulse oximetry/electrocardiography give late warnings

Procedural Sedation

- Because oxygenation and ventilation are separate though related physiological processes, monitoring oxygenation be pulse oximetry is not a substitute for monitoring ventilatory function by capnography

Practice guidelines for sedation and analgesia by non-aneshesiologists. Anesthesiology. 2002;96:1004-17

Patient Controlled Analgesia

- Difficult to predict response on patients to analgesics
  - Opiod naive patients
  - Concomitant OSA
- Respiratory monitoring is essential
- Pulse oximetry does not identify respiratory events until severe

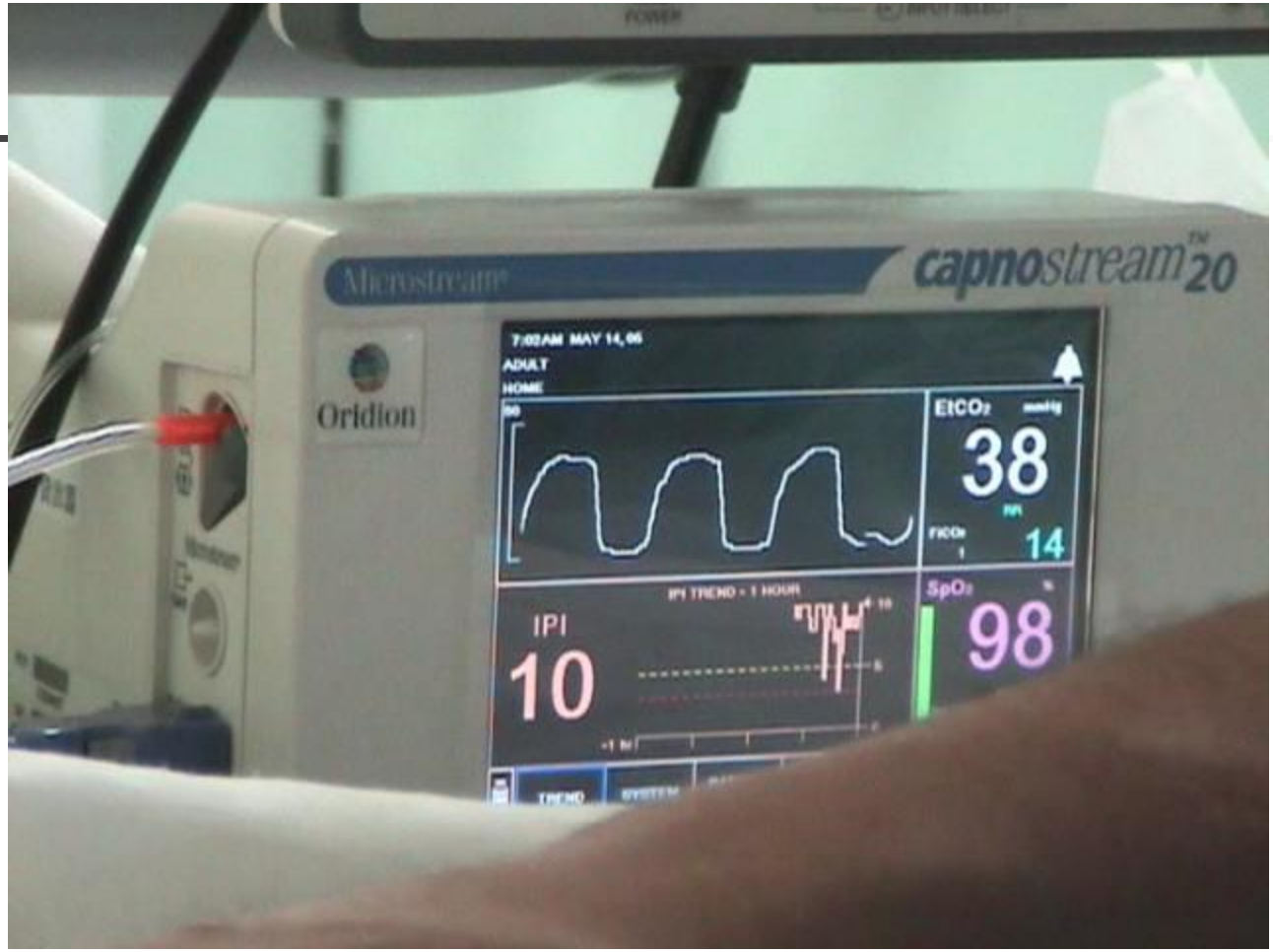
Patient Controlled Analgesia

- Report on CSJHS use of capnograpy during PCA (Am J Health-Syst Pharm. 2006:63:157-64)
- Capnography identified:
  - Respiratory depression secondary to PCA
  - PCA by proxy
  - OSA
  - Post anesthesia respiratory decline

Use in Non-human Patients

Recent Advances in Capnography

- Integrated Pulmonary Index (IPI™)
  - Developed by Oridion Capnography, Inc.
  - Received FDA (510k) clearance in Feb, 2009
- Utilizes Capnography and Pulse oximetry
  - Integrates $P_{ET}CO_2$, RR, SPO_2, and Pulse rate
  - Displays IPI™ as a single number from 1 to 10
  - 10 is good, 1 is bad


Microstream
capnostream 20
Oridion
7:02AM MAY 14,06
ADULT
HOME
EtCO2
38
14
IPI TREND - 1 HOUR
IPI
10
SpO2
98
TREND


Microstream
capnostream
Oridion
6:50AM MAY 14, 05
ADULT
HOME
50
EtCO2 mmHg
36
RR
FICO2
1
15
IPI TREND - 1 HOUR
IPI
10
10
5
0
-1 hr
SpO2 %
98
PR
BAT SEC
0
59
TREND
SYSTEM
PATIENT TYPE
ALARMS
PRINT
ZOOM IPI


Microstream
capnostream
Oridion
6:51AM MAY 14, 05
ADULT
HOME
50
EtCO2 mmHg
15
RR
FICO2
0
18
IPI TREND - 1 HOUR
IPI
4
10
5
0
-1 hr
SpO2
%
97
PR
BAT SEC
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59
TREND
SYSTEM
PATIENT TYPE
ALARMS
PRINT
ZOOM IPI

Purpose of IPI™/Capnography

- Increase patient safety
  - Allows early recognition of changing respiratory status
- Improve patient care and outcome
  - Monitors changes in patient condition during interventions and therapy
- Enhances clinical decisions
  - Simple, clear indicator of patient respiratory status and trends
  - Facilitates communication of patient's respiratory status

How does IPI work?

- $P_{ET}CO_2$, RR, SPO_2, PR are continuously monitored and displayed (Capnostream 20™)
- Integrated into single, displayed number
- IPI™ algorithm uses fuzzy logic model built from opinions of medical experts (MD, RN, RRT, PhD)
- Scale:
  - 7-10: Normal
  - 5-6: Requires attention
  - 3-4: Requires attention, may require intervention
  - 1-2: Requires intervention

Clinical Studies on IPI to Date

- Presented at STA meeting, Jan. 2009:
  - Reliability of the Integrated Pulmonary Index Postoperatively. Y. Gozal, MD, D. Gozal, MD
  - The Integrated Pulmonary Index: Validity and Application in the Pediatric Population. D. Gozal, MD, Y. Gozal, MD
- Conclusions:
  - IPI correlates well with respiratory status in pediatric patients undergoing procedures under deep sedation and adult patients in a PACU after surgery under general anesthesia
  - IPI would be useful for non-expert personnel monitoring patients undergoing procedures requiring deep sedation or recovering from them
  - IPI may simplify patient monitoring in a busy unit

Clinical Studies on IPI to Date

- Presented at NAEMS-P meeting, Jan. 2010:
  - Analysis Of Abnormal Events Identified By The Integrated Pulmonary Index (IPI) In Normal Adults During Noninvasive Positive Pressure Ventilation. JB Waugh, AA Taft, KH Niebel
- Conclusions:
  - IPI appears to allow detection of abnormal breathing events caused by overventilation, rapid shallow breathing, and bradypnea. These abnormal events were not identified by pulse oximetry and may not have been recognized with traditional capnography.

Possible Uses for IPI

- Indicator of ventilatory status
- Monitors ventilatory status during interventions
  - Ventilator Weaning (SBT)
  - Procedural sedation/PCA
  - MET call
  - At risk patient on general floor
  - EMS transport (prehospital)

Starting a Capnography Program

- RTs must be resources and advocates
  - Understand underlying physiology and correlate with capnography results
  - Advocate using capnography
  - RTs must be the “experts”
  - Demonstrate uses for capnography
- We must convince clinicians that using capnography improves patient care

In Conclusion:

- Capnography is useful for monitoring ventilatory function
  - Provides early warning of potentially deleterious ventilatory events
  - Can be safely and easily performed on non-intubated patients
  - IPI may simplify and enhance the use of capnography