Noninvasive Monitoring of Gas Exchange: Questions Answered

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Conflict of Interest

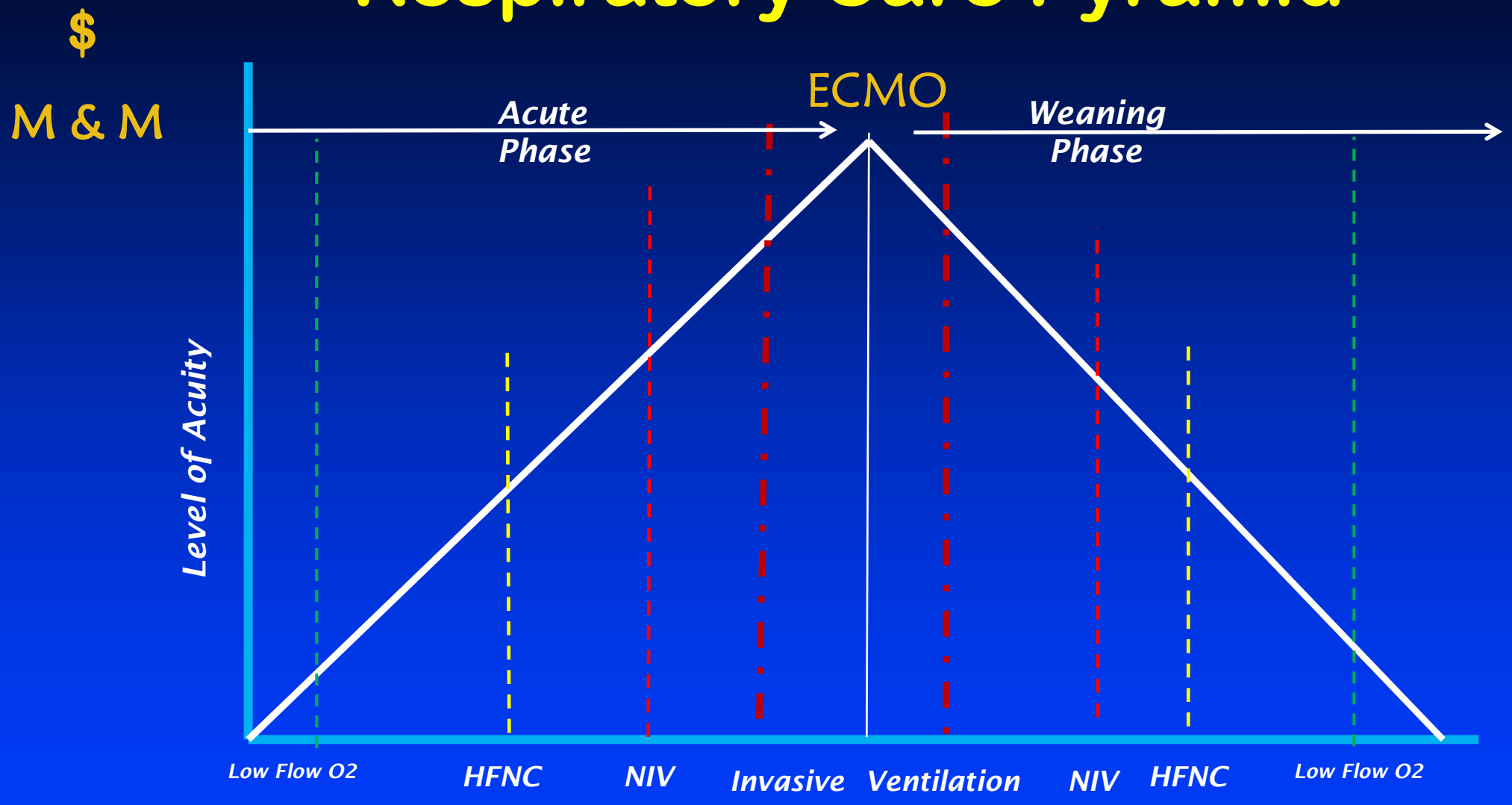
I have no real or perceived conflict of interest that relates to this presentation.

Any use of brand names is not in any way meant to be an endorsement of a specific product, but to merely illustrate a point of emphasis.

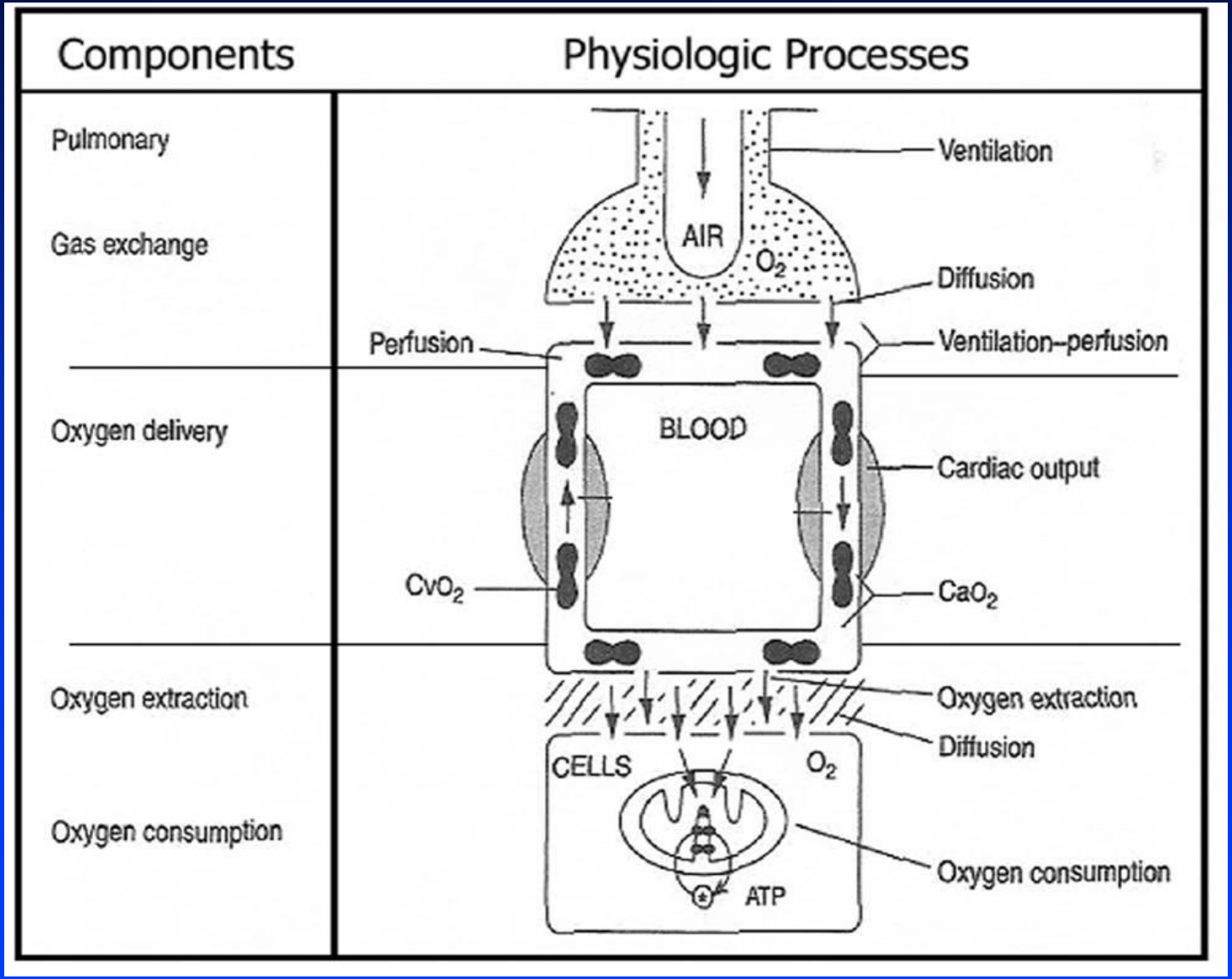
Objectives

- Describe the correlation of noninvasive monitoring and other physiologic measurements.
- Identify the technology available for noninvasive monitoring of gas exchange.
- Identify clinical areas in which noninvasive monitoring may help to improve patient assessment and treatment.

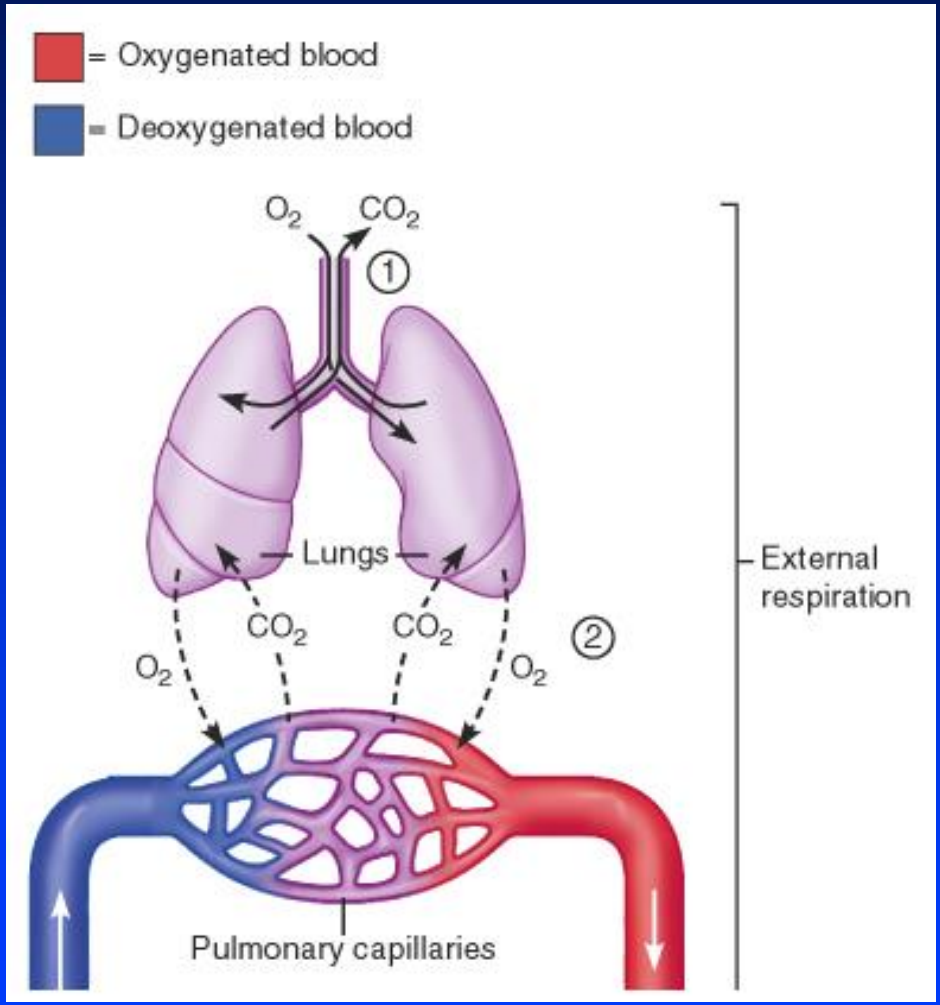
Respiratory Care Pyramid

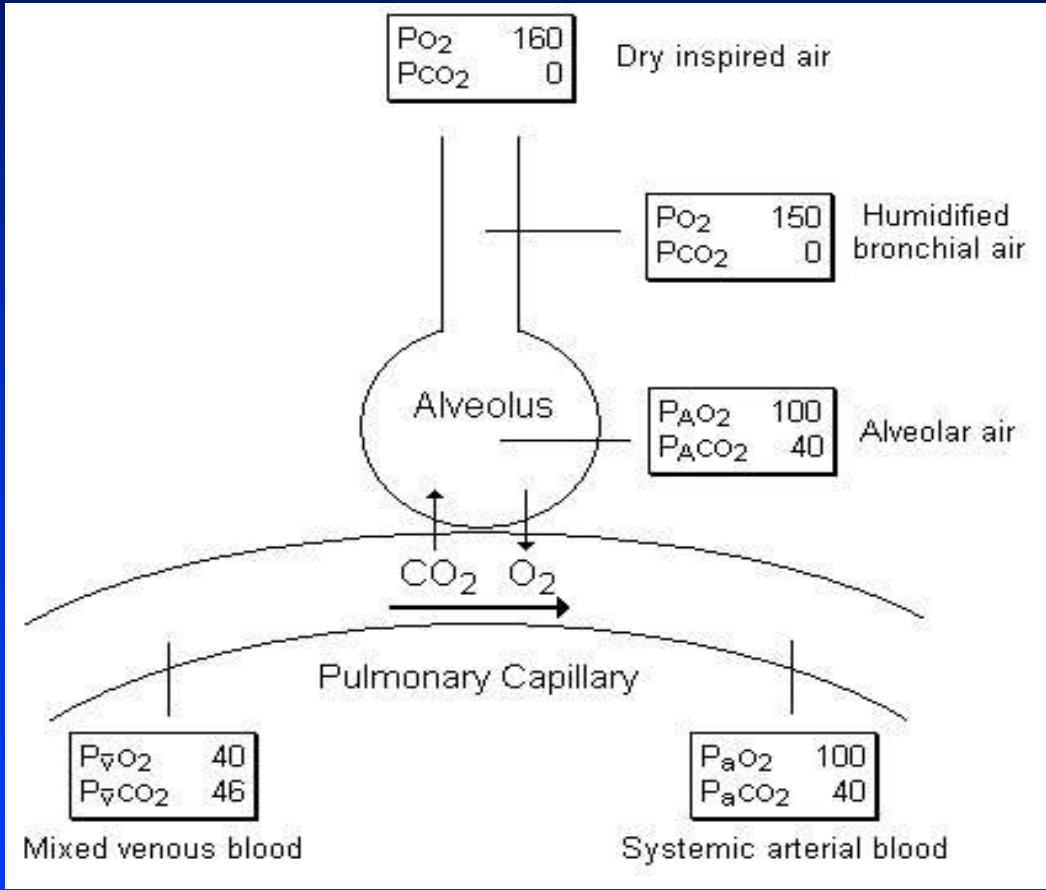


Rationale

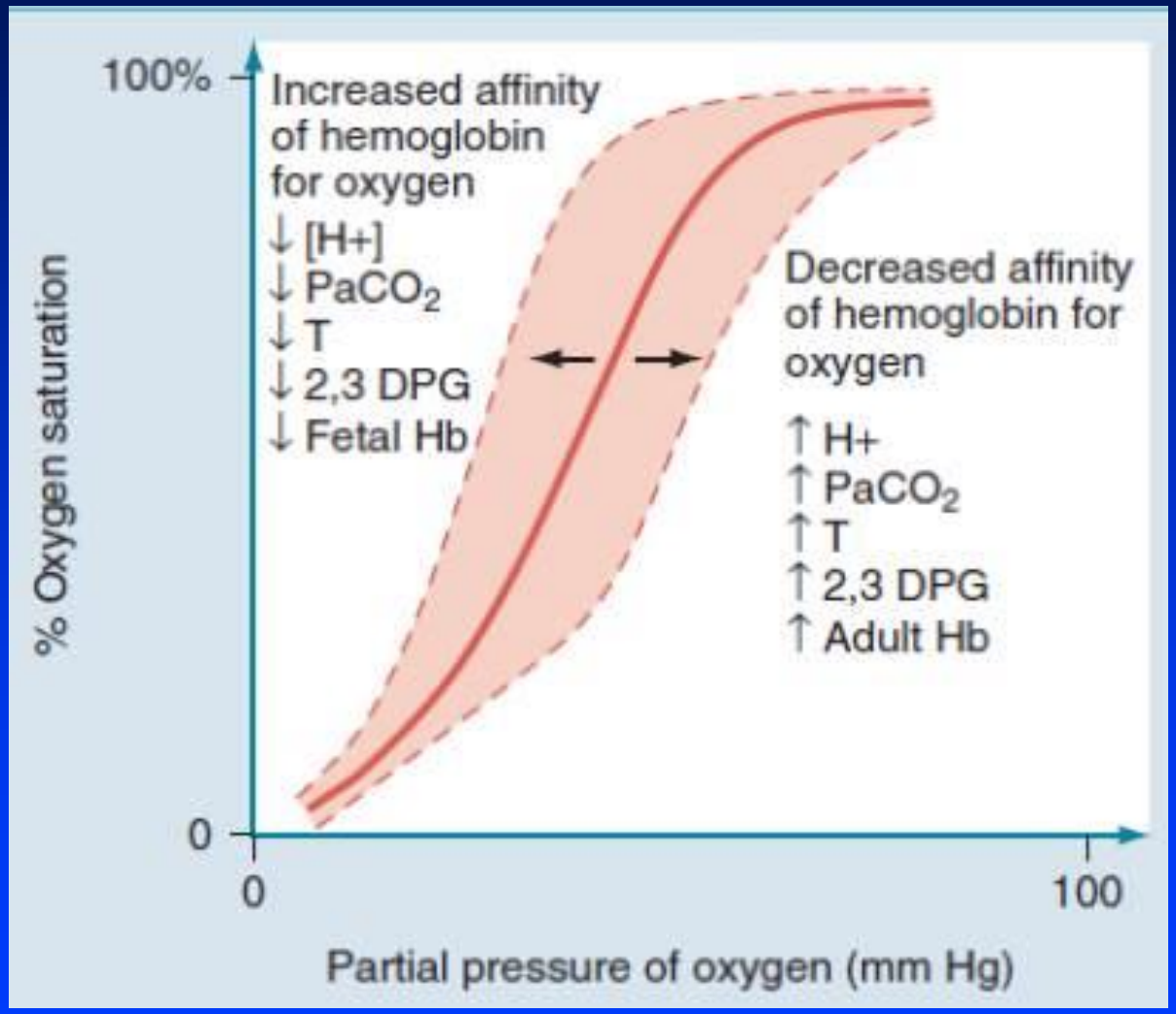

Components
Physiologic Processes
Pulmonary
Gas exchange
Oxygen delivery
Oxygen extraction
Oxygen consumption
Ventilation
AIR
O_2
Diffusion
Perfusion
Ventilation–perfusion
BLOOD
Cardiac output
CvO_2
CaO_2
Oxygen extraction
Diffusion
CELLS
O_2
Oxygen consumption
ATP

Blood and Air





Linking Oxygenation & Ventilation



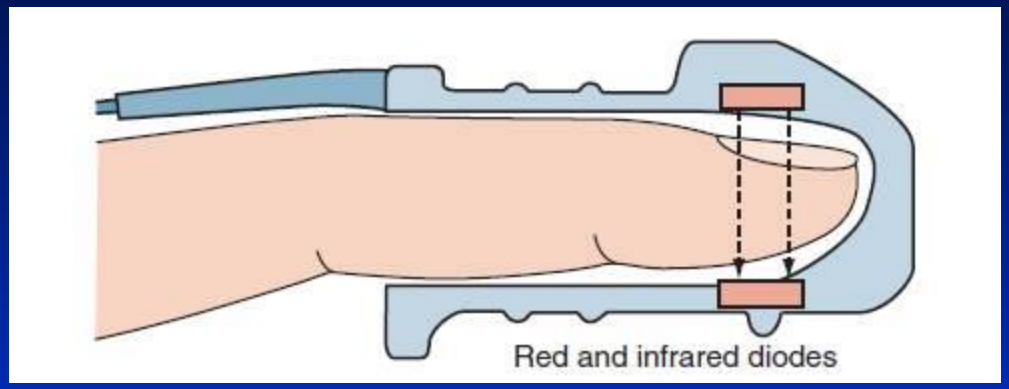
Vital Signs

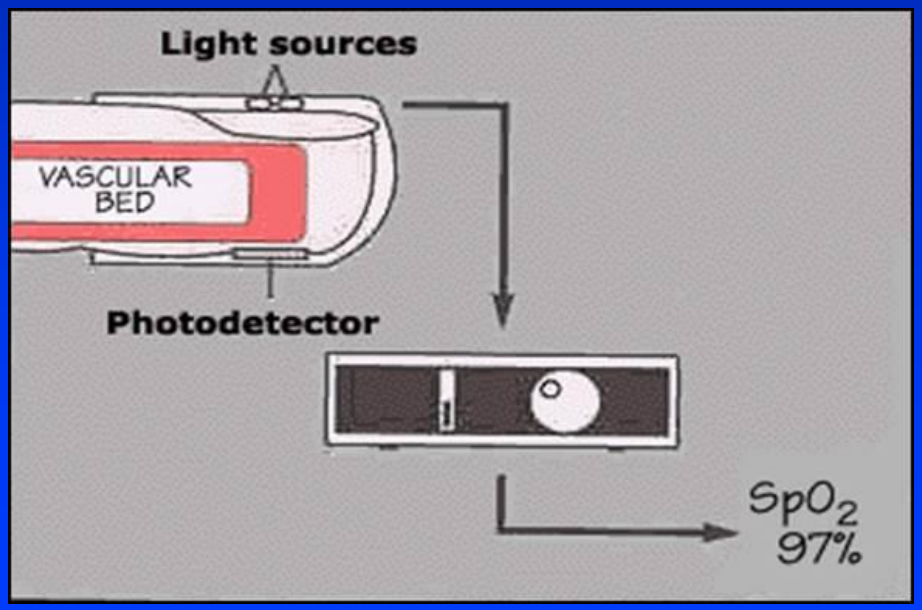
- Heart Rate
- Blood Pressure
- Temperature
- Respiratory Rate

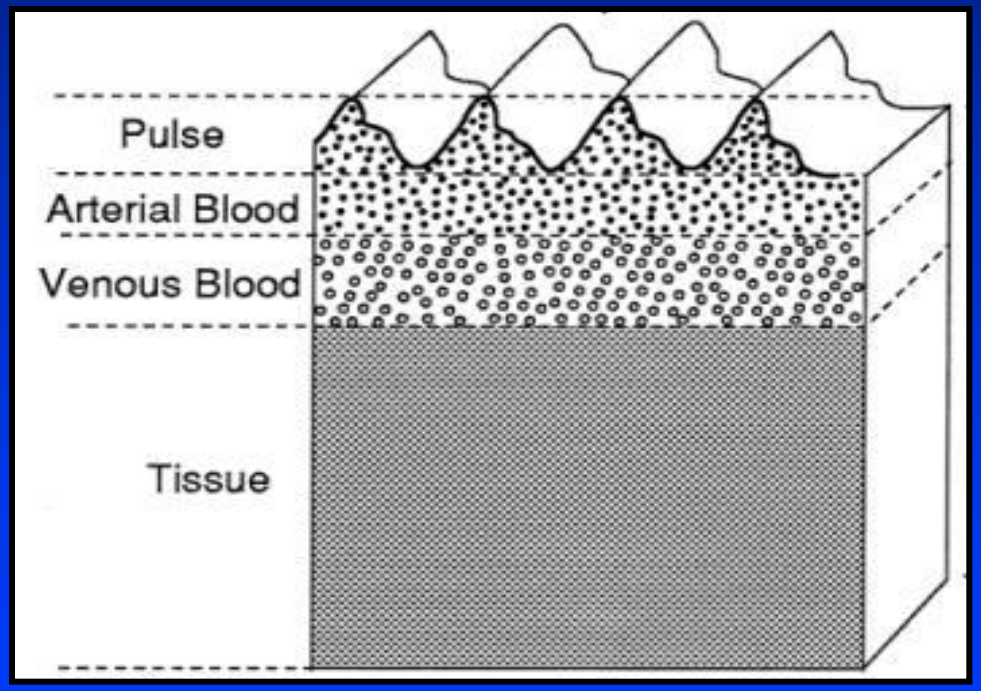
ABG vs. Continuous Monitoring

- Arterial Blood Gases
- Pulse Oximetry (SpO_2)
- Capnography ($ETCO_2$)
- Transcutaneous (SpO_2/CO_2)

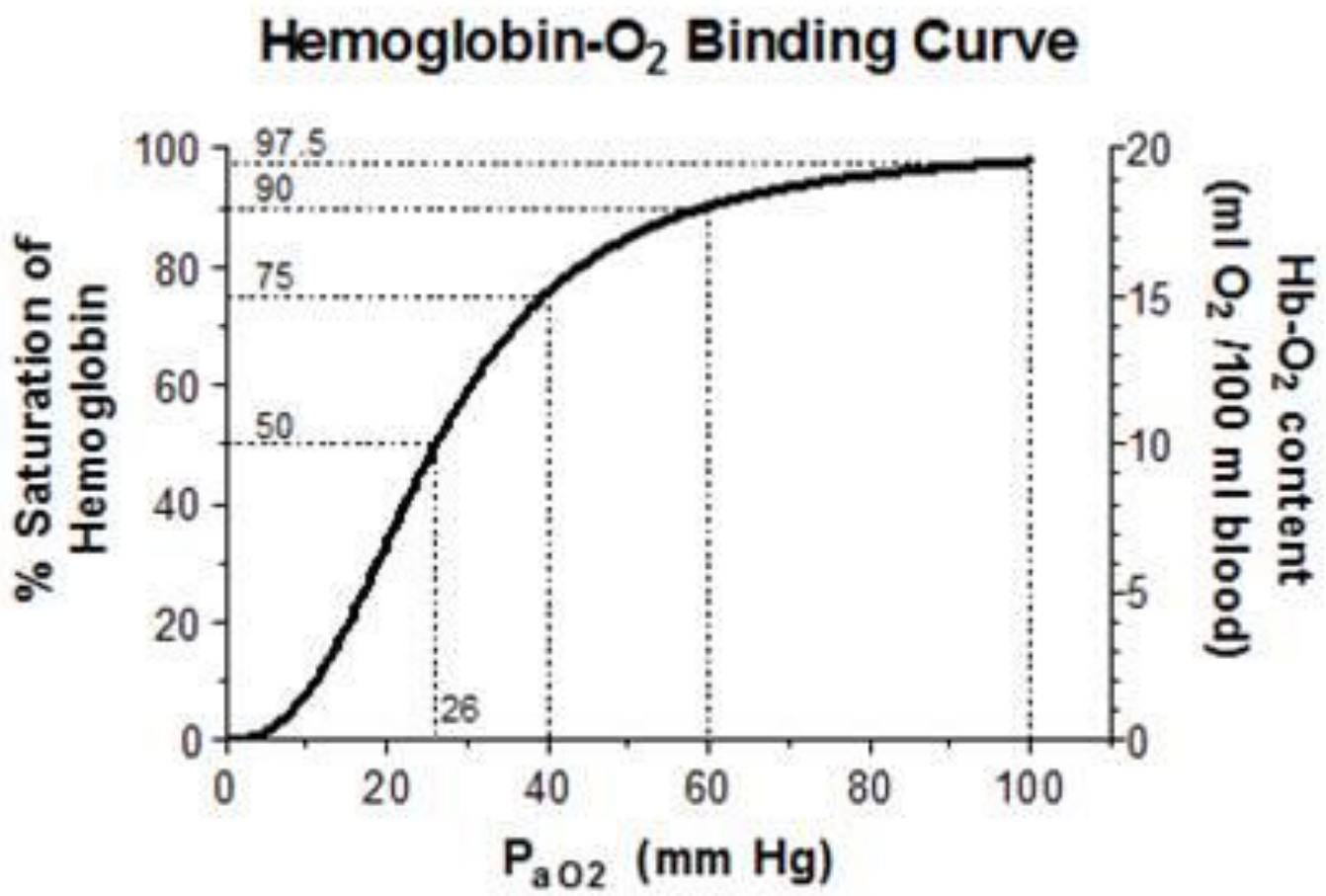
Pulse Oximetry

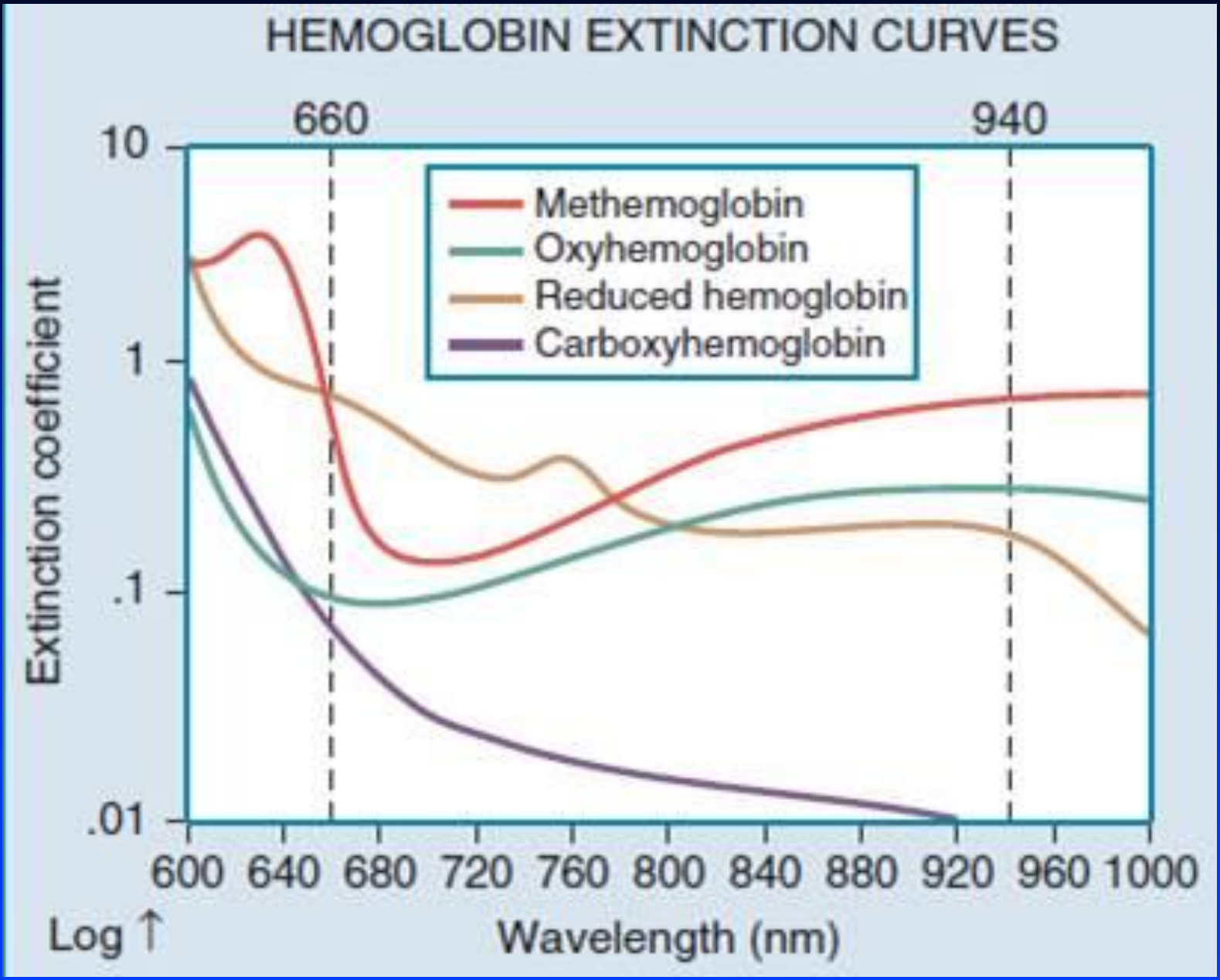






SpO_2 Value


Hemoglobin-O2 Binding Curve
% Saturation of Hemoglobin
Hb-O2 content (ml O2 /100 ml blood)
PaO2 (mm Hg)
97.5
90
75
50
26
0
20
40
60
80
100
0
5
10
15
20


HEMOGLOBIN EXTINCTION CURVES
660
940
10
1
.1
.01
Extinction coefficient
Methemoglobin
Oxyhemoglobin
Reduced hemoglobin
Carboxyhemoglobin
600 640 680 720 760 800 840 880 920 960 1000
Log ↑
Wavelength (nm)

Equipment

Amazon.com: pulse oxim

https://www.amazon.com/s/ref=sr_st_relevanceblender?keywords=pulse+oximeter&rh=i%3Aaps%2Ck%3Apulse+oximeter&qid=1481162208&sort=relevanceblender

Apps | The University of Mou | Duke University Hosp | Inbox (33) - mag4325 | Purdue OWL: APA For | The Hillsborough Han | Google | Early ICU Ventilators | Quick and Easy Pizza

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categories | deals | pulse oximeter | my account sign in | 0 items

"pulse oximeter"

11 items

filter results

sort by **relevance**

category
health (11)

type
- Pulse Oximeter (11)

age
- Adult (18 years and up) (9)
- Child (3-9 years) (1)
- Senior (65 years and

related searches

fingertip pulse oximeter | finger pulse oximeter | pulse oximeter baby

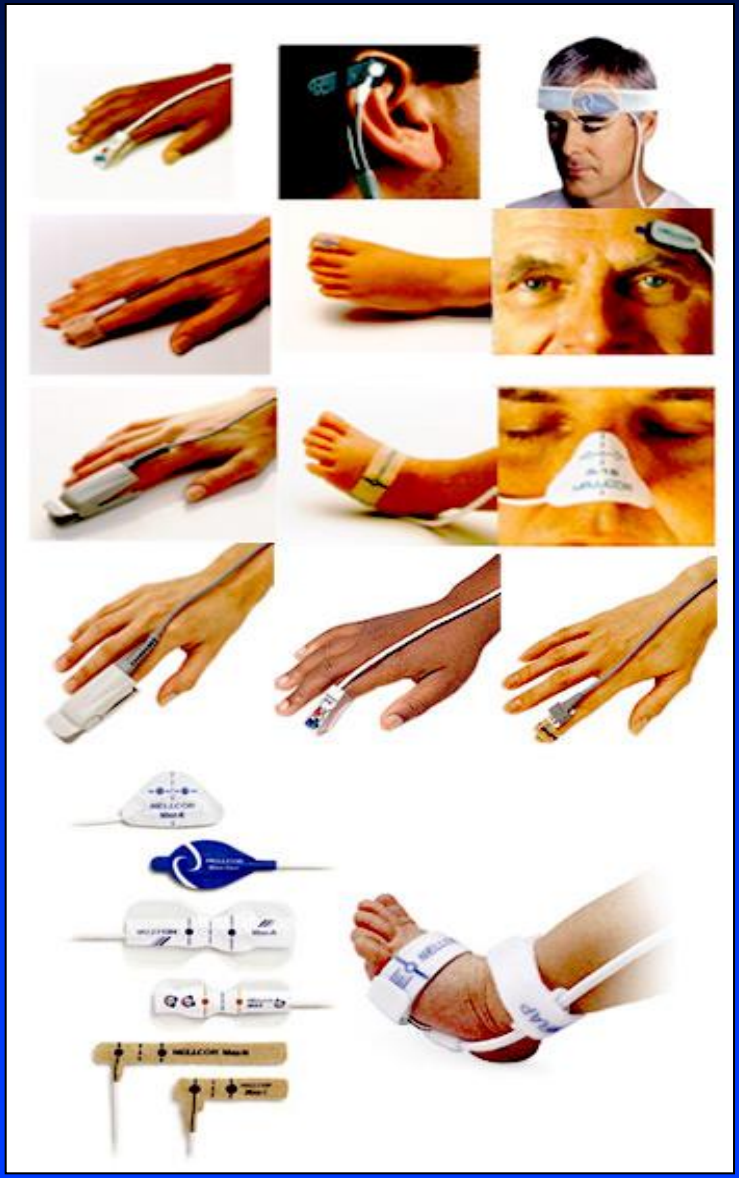
Equipment


Breakthrough Measurements. Radical Monitor.
Radical-7®
To learn more,
click here >>

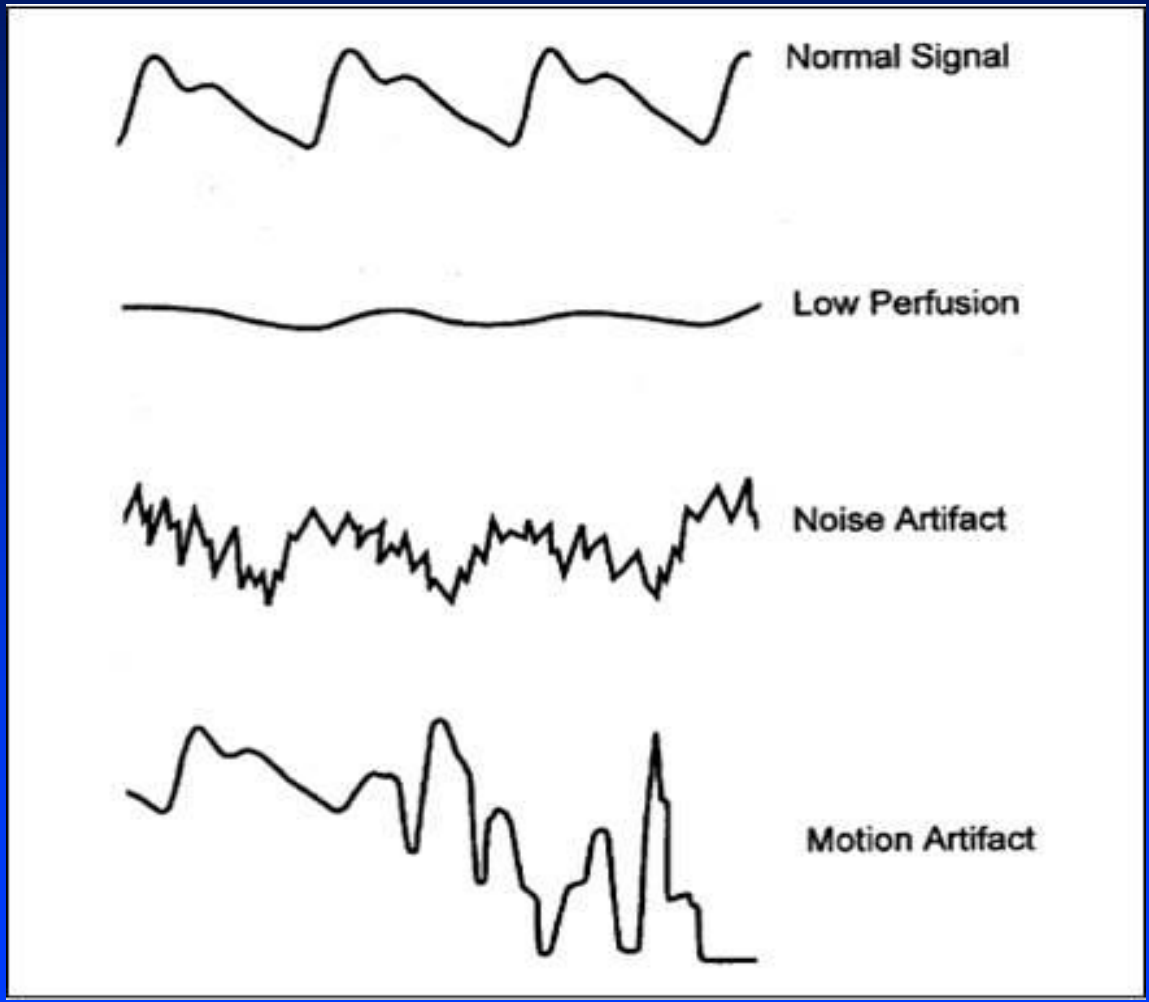

NELLCOR
98
64


99
75
2.0

Probe Selection and Placement



Issues with Pulse Oximetry



Factor	*Effect*
Carboxyhemoglobin (COHb)	Slight reduction of the assessment of oxygen saturation (Sao_2) by pulse oximetry (Spo_2) (i.e., overestimates the fraction of hemoglobin available for O_2 transport)
Methemoglobin (MetHb)	At high levels of MetHb, Spo_2 approaches 85%, independent of actual Sao_2
Methylene blue	Transient, marked decrease in Spo_2 lasting up to several minutes; possible secondary effects as a result of effects on hemodynamics
Anemia	If Sao_2 is normal, no effect; during hypoxemia with Hb values less than 14.5 g/dL, progressive underestimation of actual Sao_2
Ambient light interference	Bright light, particularly if flicker frequency is close to a harmonic of the light-emitting diode switching frequency, can falsely elevate the Spo_2 reading
Blood flow	Reduced amplitude of pulsations can hinder obtaining a reading or cause a falsely low reading.
Motion	Movement, especially shivering, may depress the Spo_2 reading.
Nail polish	Slight decrease in Spo_2 reading, with greatest effect using blue nail polish, or no change
Sensor contact	"Optical shunting" of light from source to detector directly or by reflection from skin results in falsely low Spo_2 reading.
Skin pigmentation	Small errors or no significant effect reported; deep pigmentation can result in reduced signal.
Tape	Transparent tape between sensor and skin has little effect; falsely low Spo_2 has been reported when smeared adhesive is in the optical path.
Vasodilatation	Slight decrease
Venous pulsation	Artifactual decrease in Spo_2

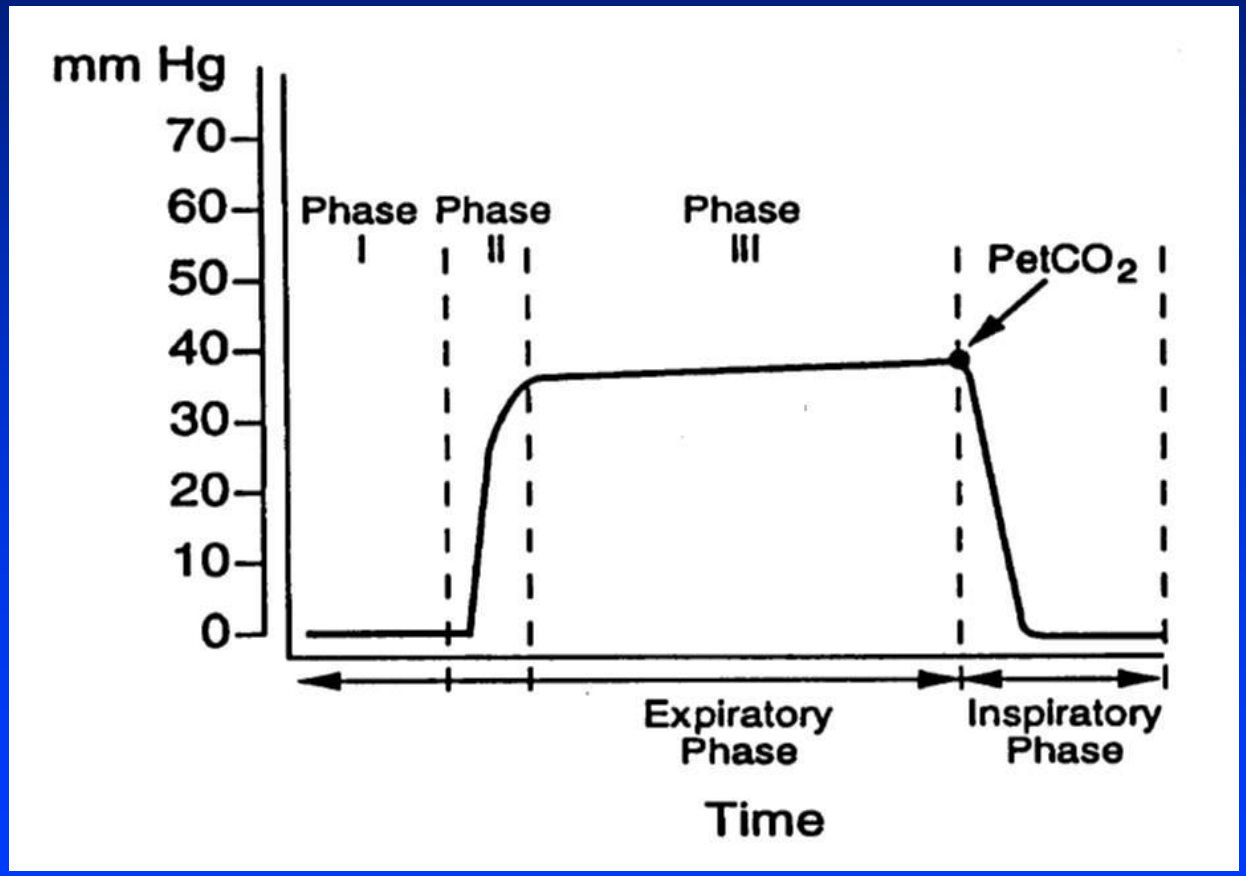
THERMAL IMAGE OF A HEALTHY ADULT IN A COLD ROOM

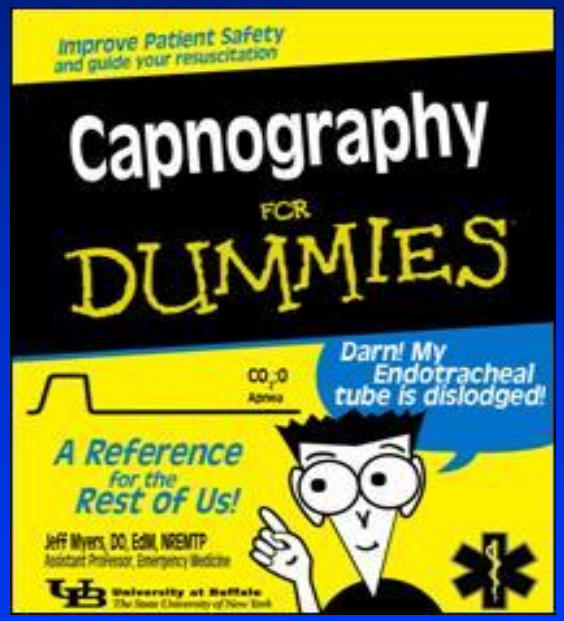
EXTREMITIES VERSUS THE FOREHEAD

Practice Pearls

- When in doubt, feel for a pulse (signal strength matters)
- Consider SpO_2 a diagnostic tool
- Know the limitations of the technology
- Correlate patient condition with SpO_2 reading
- Use the right probe for the situation
- Know the technology (you are the expert)

Capnography: End Tidal CO_2





Capnography Clinical Applications

- Verification of ETT Placement
- CPR
- Trend $ETCO_2$
- Brain death study
- Conscious sedation
- Patient transport
- Deadspace measurement

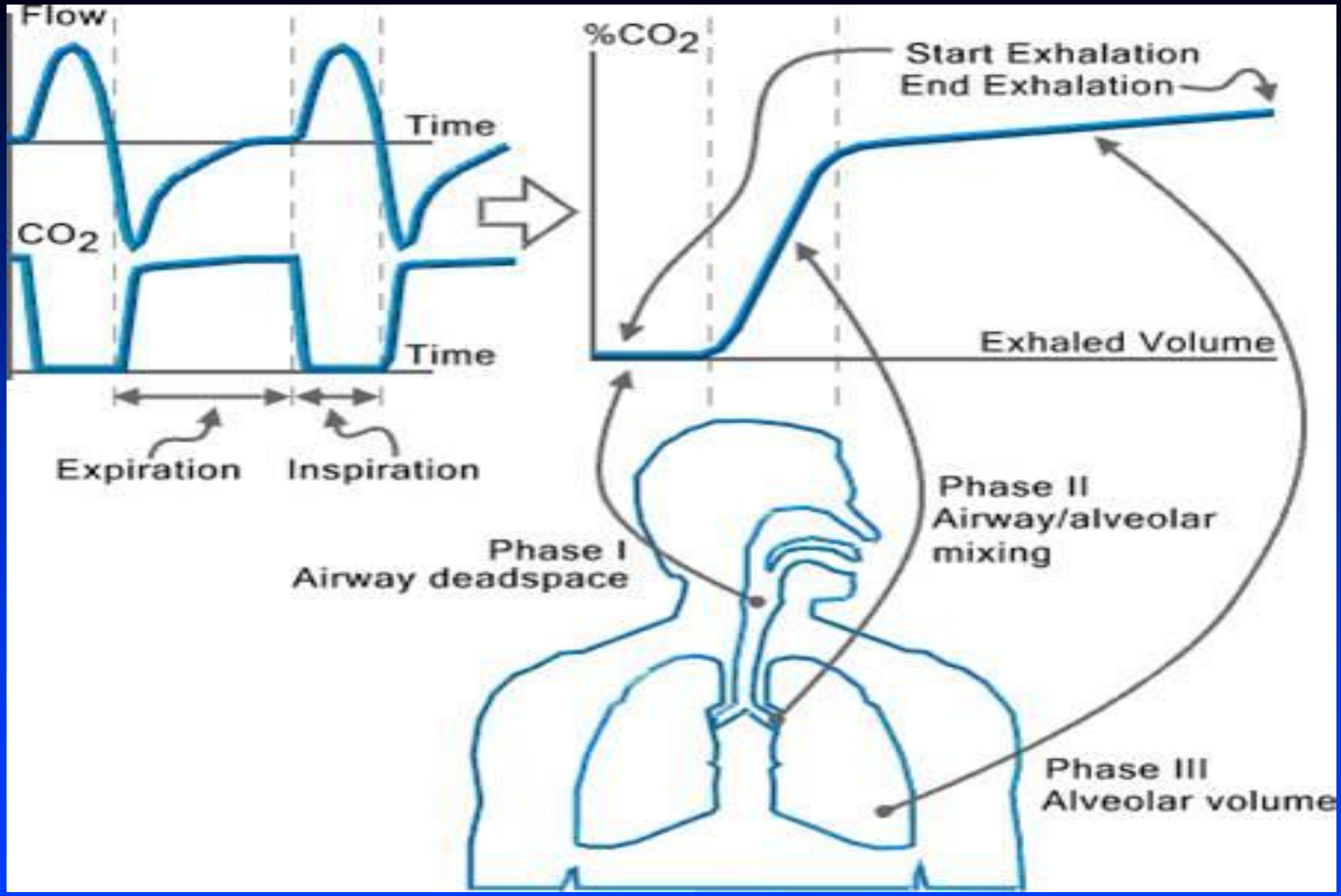
SpO_2 versus $ETCO_2$

Pulse Oximetry

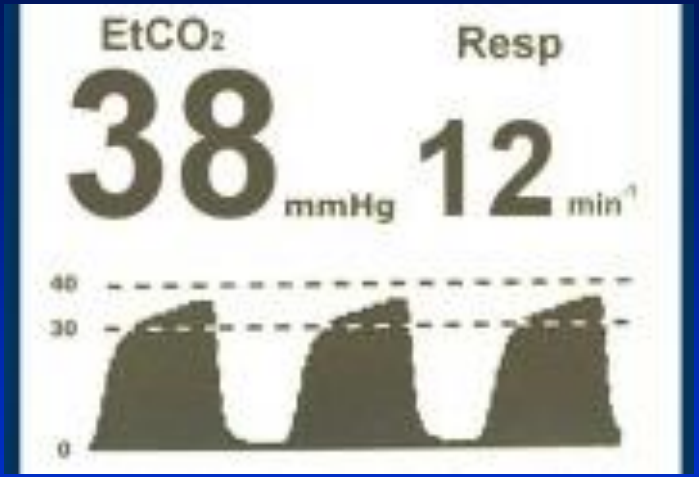
- Oxygen saturation
- Reflects oxygenation
- SpO_2 changes lag when patient is hypoventilating or apneic
- Should be used with capnography

Capnography

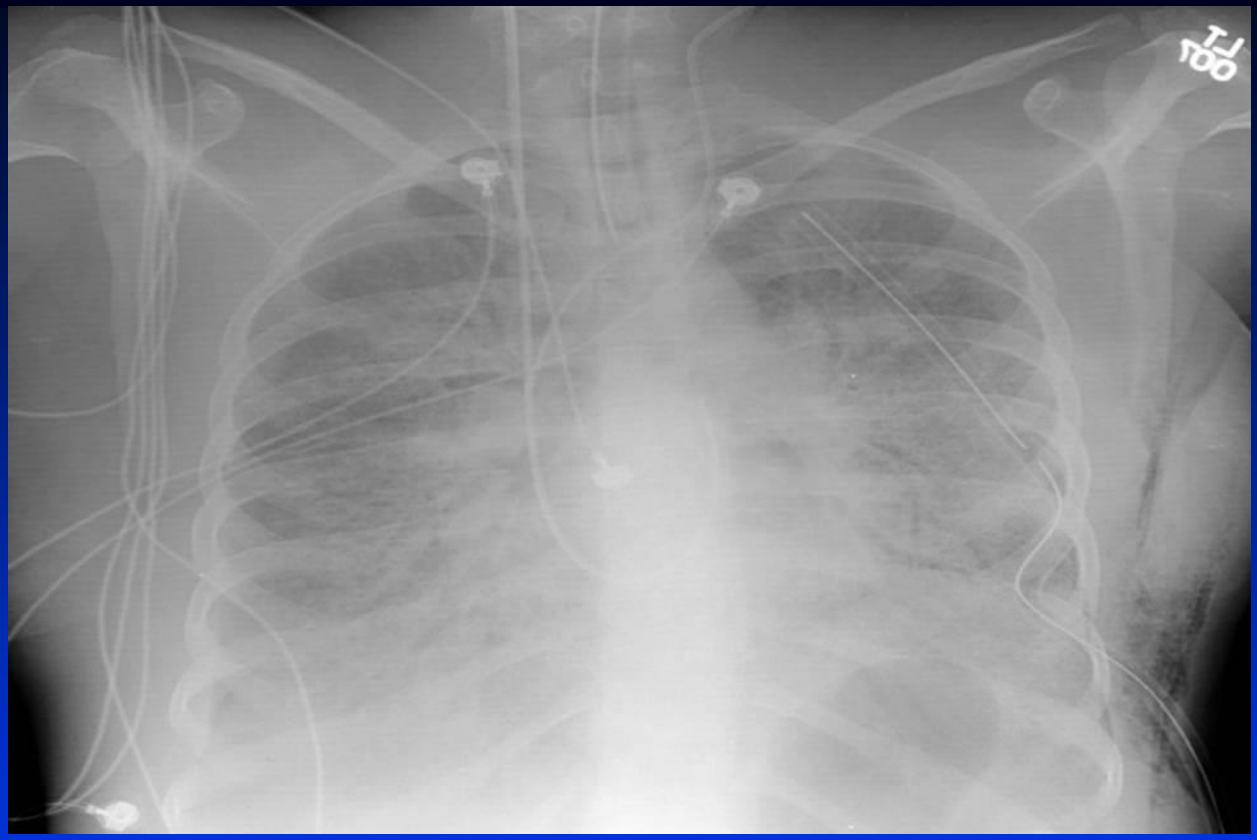
- Carbon dioxide
- Reflects ventilation
- Hypoventilation or apnea detected immediately
- Should be used with pulse oximetry

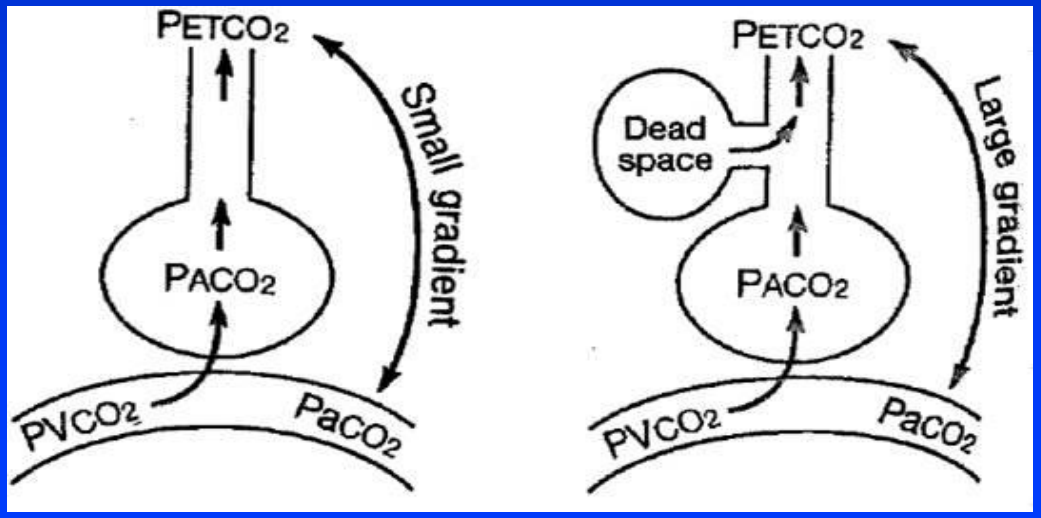

Flow
Time
CO_2
Time
Expiration
Inspiration
%CO_2
Start Exhalation
End Exhalation
Exhaled Volume
Phase I
Airway deadspace
Phase II
Airway/alveolar
mixing
Phase III
Alveolar volume

Equipment



Deadspace




PETCO2
PACO2
PVCO2
PaCO2
Small gradient
PETCO2
Dead space
PACO2
PVCO2
PaCO2
Large gradient

The New England Journal of Medicine

PULMONARY DEAD-SPACE FRACTION AS A RISK FACTOR FOR DEATH IN THE ACUTE RESPIRATORY DISTRESS SYNDROME

THOMAS J. NUCKTON, M.D., JAMES A. ALONSO, R.R.T., RICHARD H. KALLET, R.R.T., M.S., BRIAN M. DANIEL, R.R.T., JEAN-FRANÇOIS PITTET, M.D., MARK D. EISNER, M.D., M.P.H., AND MICHAEL A. MATTHAY, M.D.

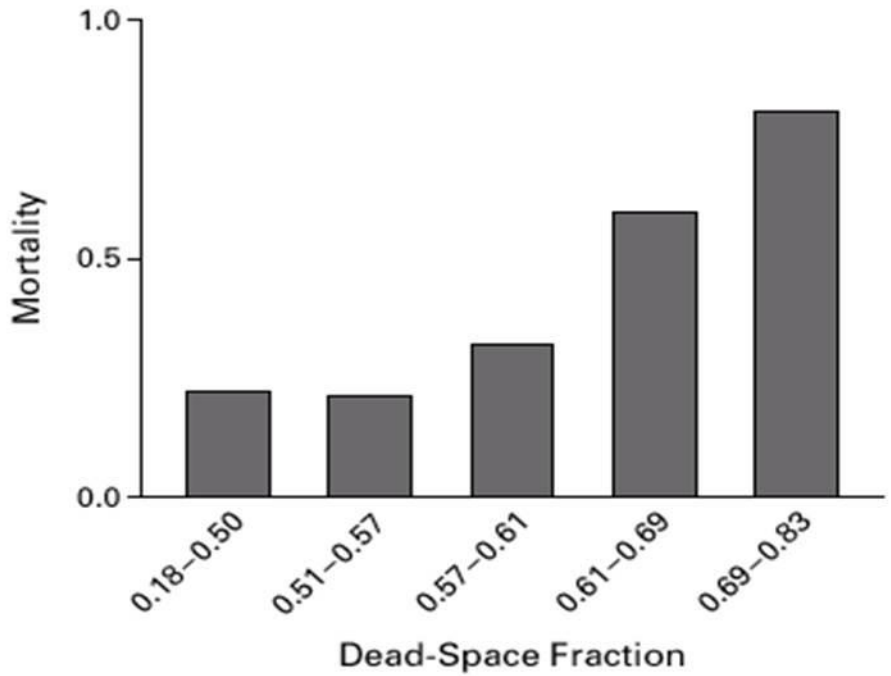


Figure 1. The Observed Mortality According to the Quintile of Dead-Space Fraction in 179 Patients with the Acute Respiratory Distress Syndrome.

AARC Clinical Practice Guideline

Capnography/Capnometry During Mechanical Ventilation: 2011

Brian K Walsh RRT-NPS FAARC, David N Crotwell RRT-NPS, and Ruben D Restrepo MD RRT FAARC

RESPIRATORY CARE • APRIL 2011 VOL 56 NO 4

- Waveform / colorimetric device for ETT placement verification.
- Use as a guide for mechanical ventilator management.
- Use during transport of intubated patient.
- Identification of exhalation abnormalities.
- Measure and manage Vd/Vt.
- Use during CPR.

Capnography Practice Pearls

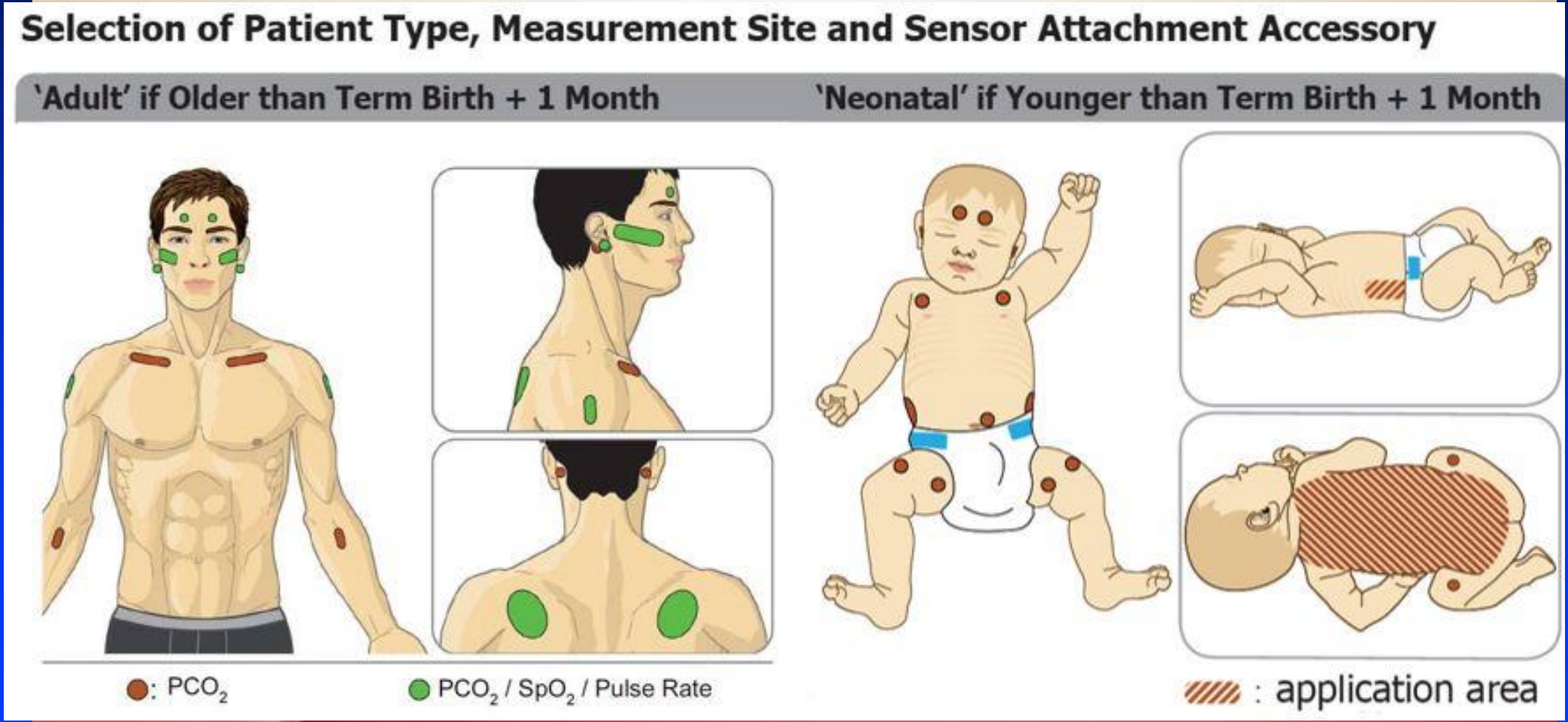
- $ETCO_2$ – $PaCO_2$ gradient reflects degree of deadspace and lung impairment.
- Sections and fluid interfere with signal.
- Minimize patient/ventilator disconnections.
- Low $ETCO_2$ values indicate trouble.
- Changes over time as patient changes.
- Issues are usually the patient, not the monitor.
- Chasing normal values may not be possible.

TC Monitoring of Gas Exchange

- Transcutaneous monitoring measures skin-surface PO_2 and PCO_2.
- Induces hyperperfusion by local warming of the skin.
- Measures partial pressure of oxygen and carbon dioxide electrochemically.
- Need to monitor the adequacy of oxygenation & ventilation in all patient populations.
- Need to measure the response to diagnostic & therapeutic interventions.

Transcutaneous Monitoring

Transcutaneous Sensor



Conscious Sedation

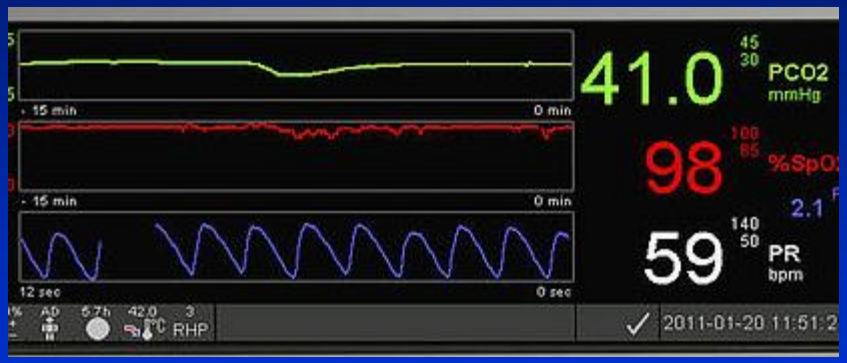
Dermatology	ENT
Radiation Oncology	ED
Bronch Suite	GI
General surgery	Urology
Interventional radiology	Dentistry
Interventional cardiology	???

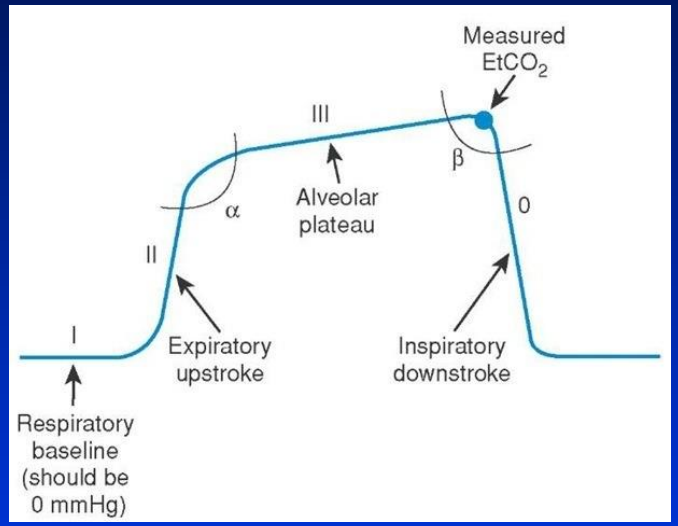
Conscious Sedation

- Planning the Administration of Moderate or Deep Sedation or Anesthesia
- "Depth & Adequacy of Respiration"
- Usually done with 3 lead ECG & SpO_2
- May trigger Rapid Response Team activity

NPPV and HFNC

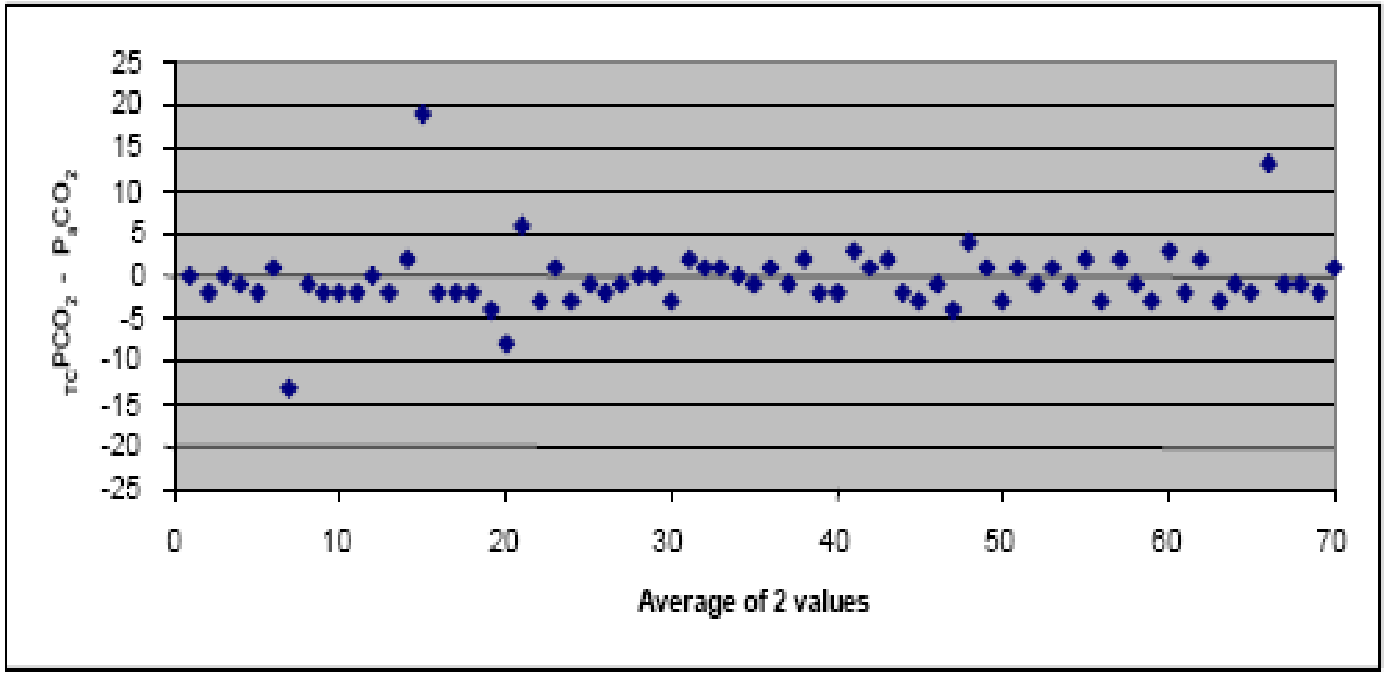
Transcutaneous vs Capnography





EVALUATION OF A NEW DIGITAL TRANSCUTANEOUS $_{TC}PCO_2$ & S_PO_2 COMBINATION SENSOR AND ITS CORRELATION TO ABG P_aCO_2 MEASUREMENTS

Daniel D. Rowley, BS, RRT-NPS, RPFT, Brian K. Walsh, BS, RRT-NPS, RPFT, Barry Young, BS, RRT, Frank J. Caruso, BS, RRT
Pulmonary Diagnostics and Respiratory Therapy Services
University of Virginia Health System, Charlottesville, Virginia

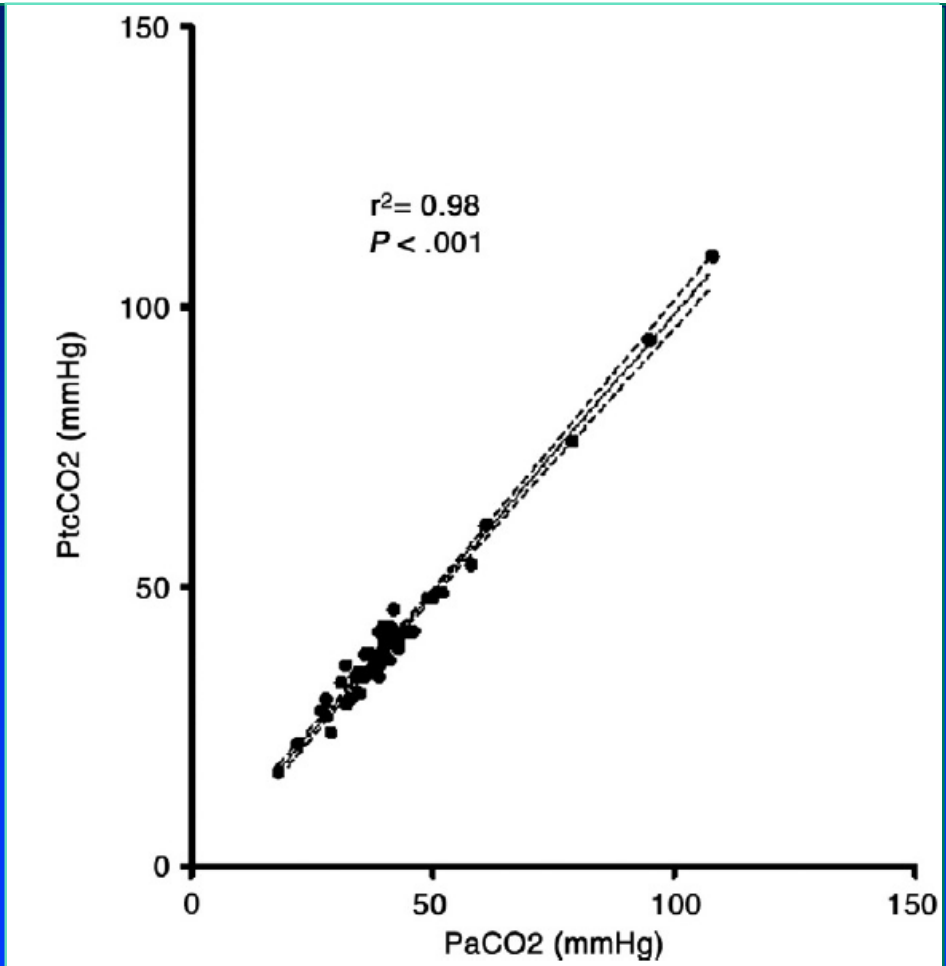


CMV (n= 45)

HFOV (n= 9)

Other (n= 16)

Concordance between transcutaneous and arterial measurements of carbon dioxide in an ED
Accuracy of transcutaneous CO_2



American Journal of Emergency Medicine (2012) xx, xxx–xxx

Range 17-109 mm Hg
Heart failure, pneumonia, asthma, COPD

Techniques for the Measurement and Monitoring of Carbon Dioxide in the Blood

Criterion	ABG	CBG	VBG	Capnography/ Capnometry	Ptc_{CO_2}
"Gold standard"	+	–	–	–	–
Accurate	+	+	–	–	–
Continuous	–	–	–	+	+
Noninvasive	–	–	–	+	+
Painless	–	–	–	+	+
Without puncture damage	–	–	–	+	+
Without blood loss	–	–	–	+	+
Rapid results/no delay	+	–	+	+	–
Additional parameters*	+	+	+	–	–
Nonskilled staff	–	+	+	+	+
Standard venous blood sample	–	–	+	–	–
No technical drift	+	+	+	+	–
Valid with perfusion–ventilation mismatch	+	+	+	–	+
Independent from leakage	+	+	+	–	+
No sleep disturbance	–	–	–	+	+
Independent from dermal perfusion	+	–	+	+	–
No artificial airway necessary	+	+	+	–	+

Ann Am Thorac Soc Vol 11, No 4, pp 645–652, May 2014

AARC Clinical Practice Guideline: Transcutaneous Monitoring of Carbon Dioxide and Oxygen: 2012

Ruben D Restrepo MD RRT FAARC, Keith R Hirst MSc RRT-NPS, Leonard Wittnebel MSIS RRT, and Richard Wettstein MMEd RRT

RESPIRATORY CARE • NOVEMBER 2012 VOL 57 NO 11

1. Correlate with ABG
2. Use to asses adequacy of ventilation
3. Use to asses tissue perfusion
4. Avoid thick skin/edema
5. Rotate sensor sights
6. Follow manufacturer recommendations

Transcutaneous Monitoring

- Neonatal to Adult population
- Sensor sites are plentiful
- Monitoring $TcPCO_2$ has appeal
- Technology has arrived
- Correlation studies have been DONE!!!!
- Help decide ABG sampling timing
- Reduce ABG samples
- Accurate data leads to clinical decisions

Summary

- Monitoring ensures rapid detection of changes in the clinical status.
- Allows for accurate assessment of progress and response interventions.
- Use non-invasive techniques when possible.
- Monitoring is crucial for patient safety

Thanks for your attention!