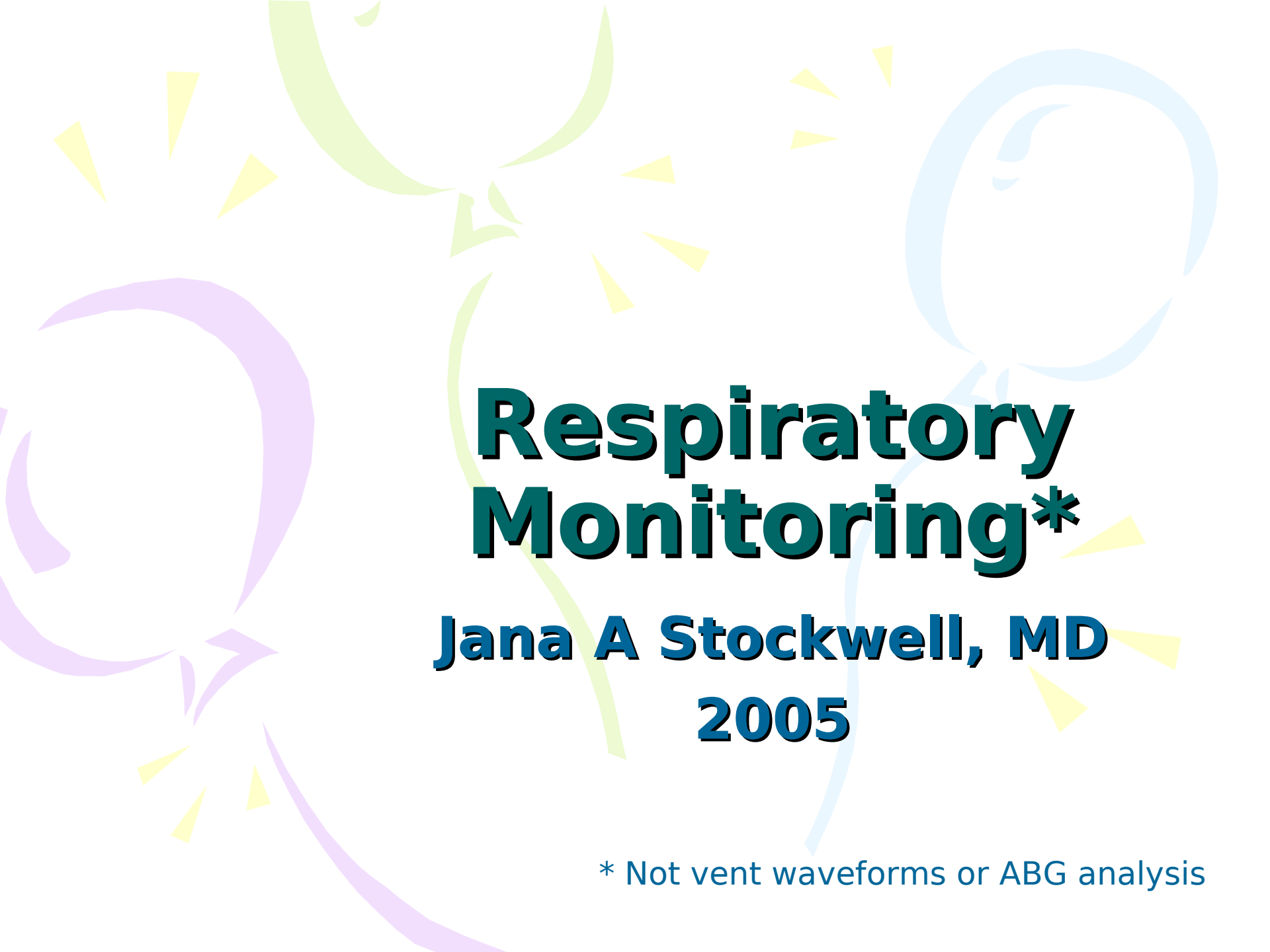
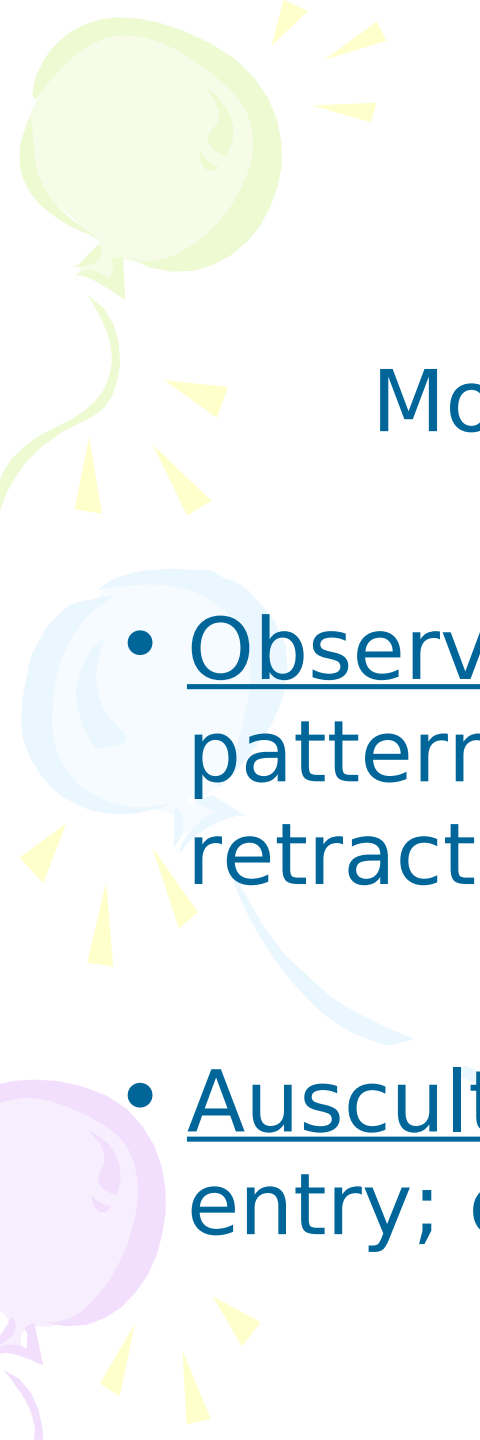


The background features several large, overlapping, hand-drawn style swirls in light green, light blue, and light purple. Scattered throughout are numerous small, yellow, four-pointed starburst shapes, giving the impression of confetti or light rays.

Respiratory Monitoring*

Jana A Stockwell, MD
2005

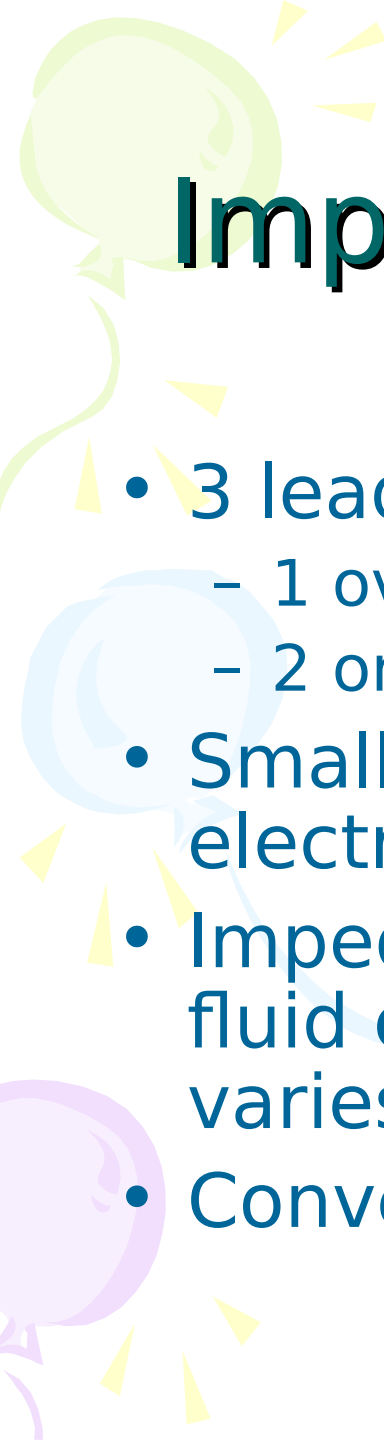
* Not vent waveforms or ABG analysis



Physical Exam

Monitor: Latin for “to warn”

- Observation: respiratory rate; pattern; color; nasal flaring; retractions; accessory muscle use
- Auscultation: wheeze; stridor; air entry; crackles; rales



Impedance Pneumography

- 3 leads-
 - 1 over the heart
 - 2 on opposite sides of the lower chest
- Small current is passed through 1 pair of electrodes
- Impedance to current flow varies with the fluid content of the chest which, in turn, varies with the respiratory cycle
- Converted into a displayed waveform



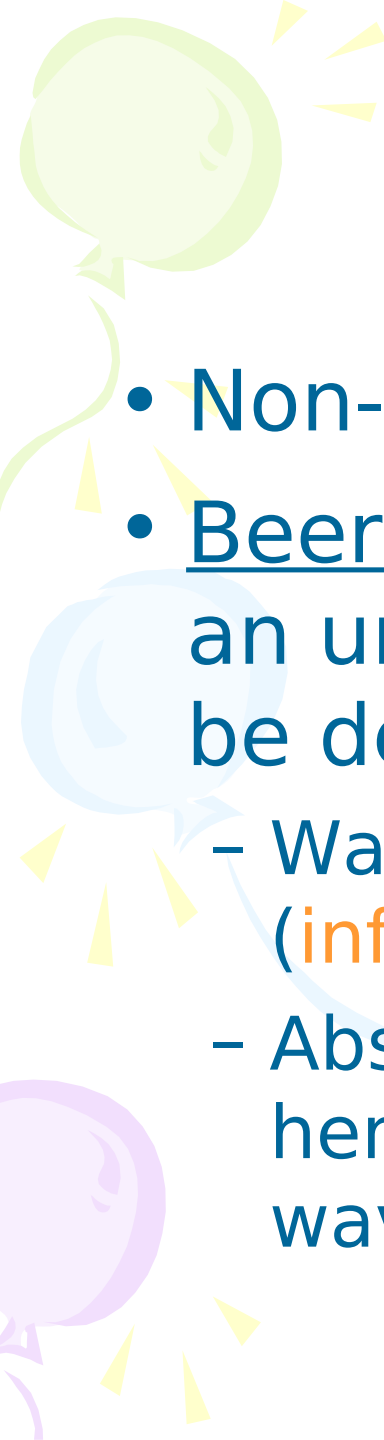
Pattern of breathing

- Pause

- Occurs in babies <3 mo, resolves by 6 months
- Last <3 seconds
- Occurs in groups of ≥ 3 , separated by <20 sec

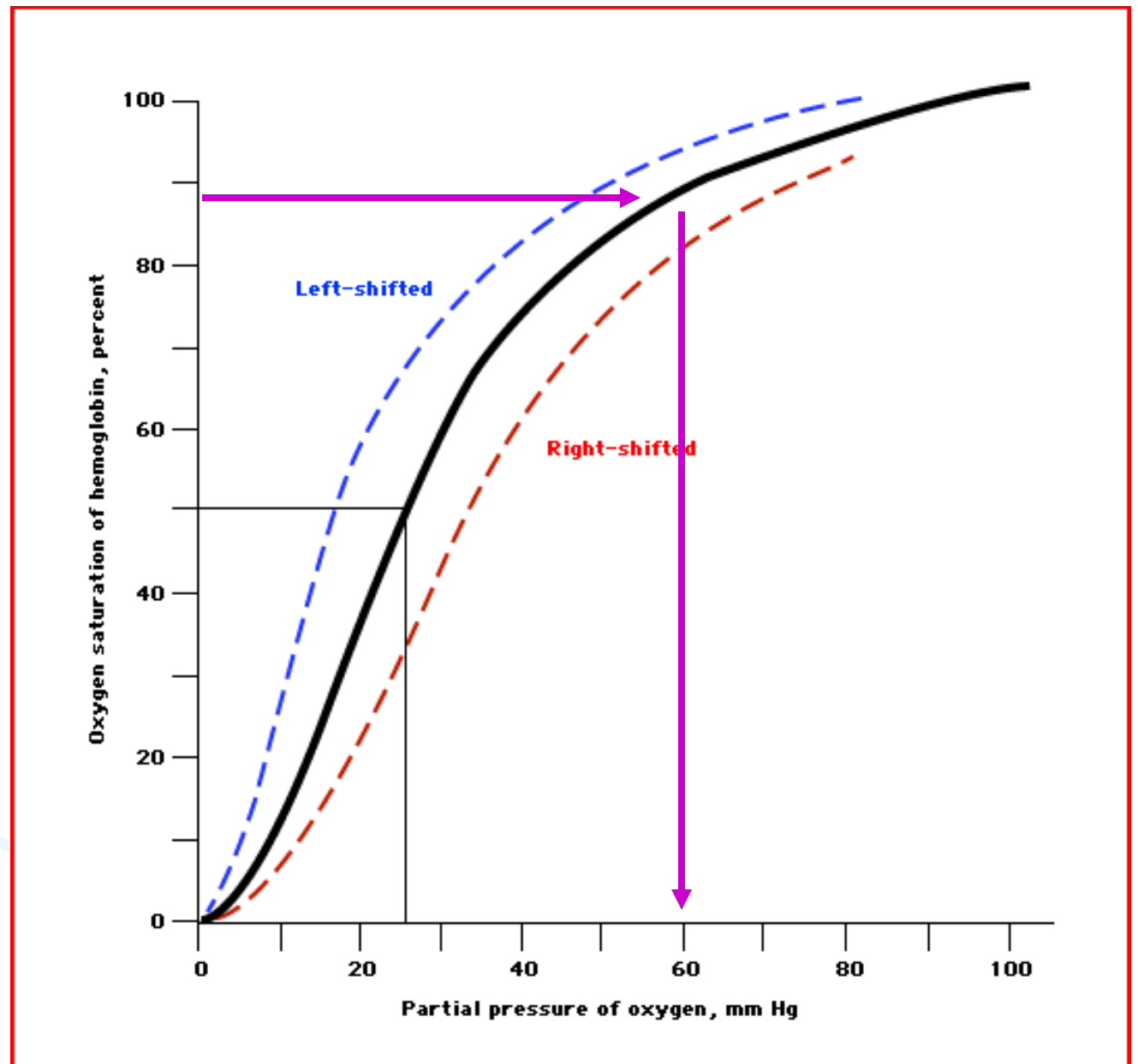
- Apnea

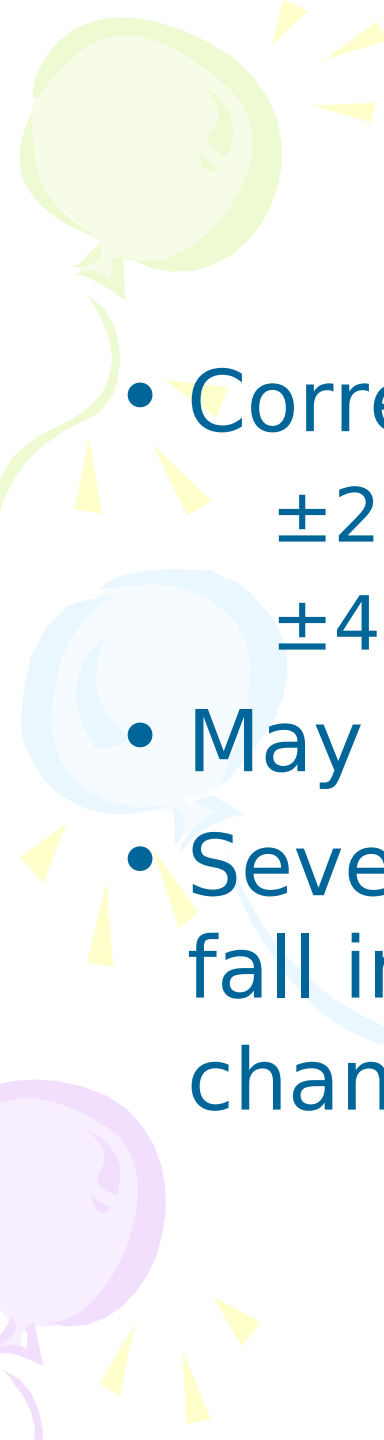
- NIH Conference consensus statement
- Cessation of breathing for longer than 20 seconds or any respiratory pause associated with bradycardia, pallor or cyanosis



Pulse Oximetry

- Non-invasively measures %HgbO₂
- Beer-Lambert law: concentration of an unknown solute in a solvent can be determined by light absorption
 - Wavelengths of 660nm (red) and 940nm (infrared)
 - Absorption characteristics of the 2 hemoglobins are different at these 2 wavelengths





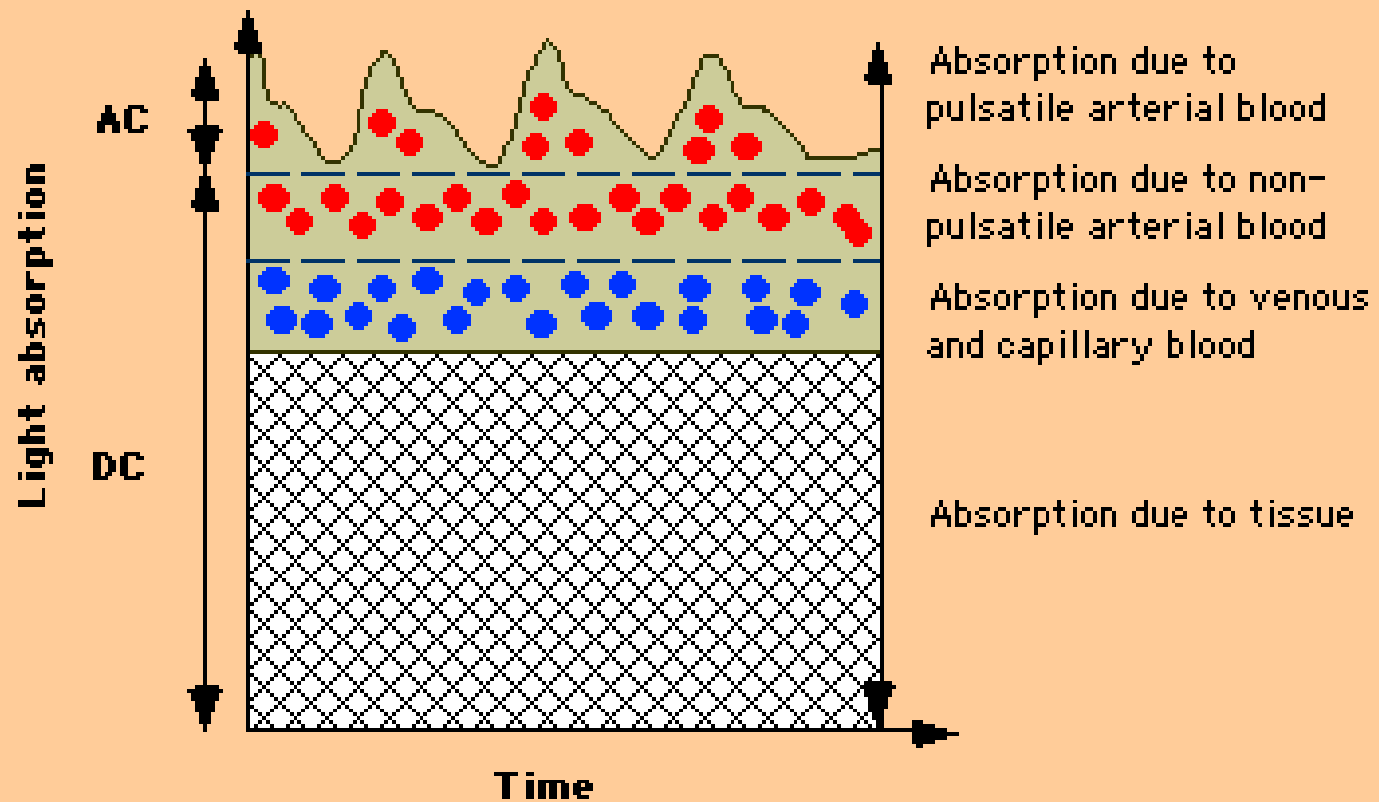
Pulse Oximetry

- Correlates well, if true sat 70-100%
 - $\pm 2\%$ of true sat 68% of time
 - $\pm 4\%$ of true sat 96% of time
- May not correlate with ABG sat
- Several studies demonstrate that a fall in SpO_2 often precedes any change in other VS



Pulse Oximetry - Mechanics

- Light source is applied to an area of the body that is narrow enough to allow light to traverse a pulsating capillary bed and sensed by a photo detector
- Each heartbeat results in a influx of oxygen saturated blood which results in increased absorption of light
- Microprocessor calculates the amounts of HgbO_2 and reduced Hgb to give the saturation

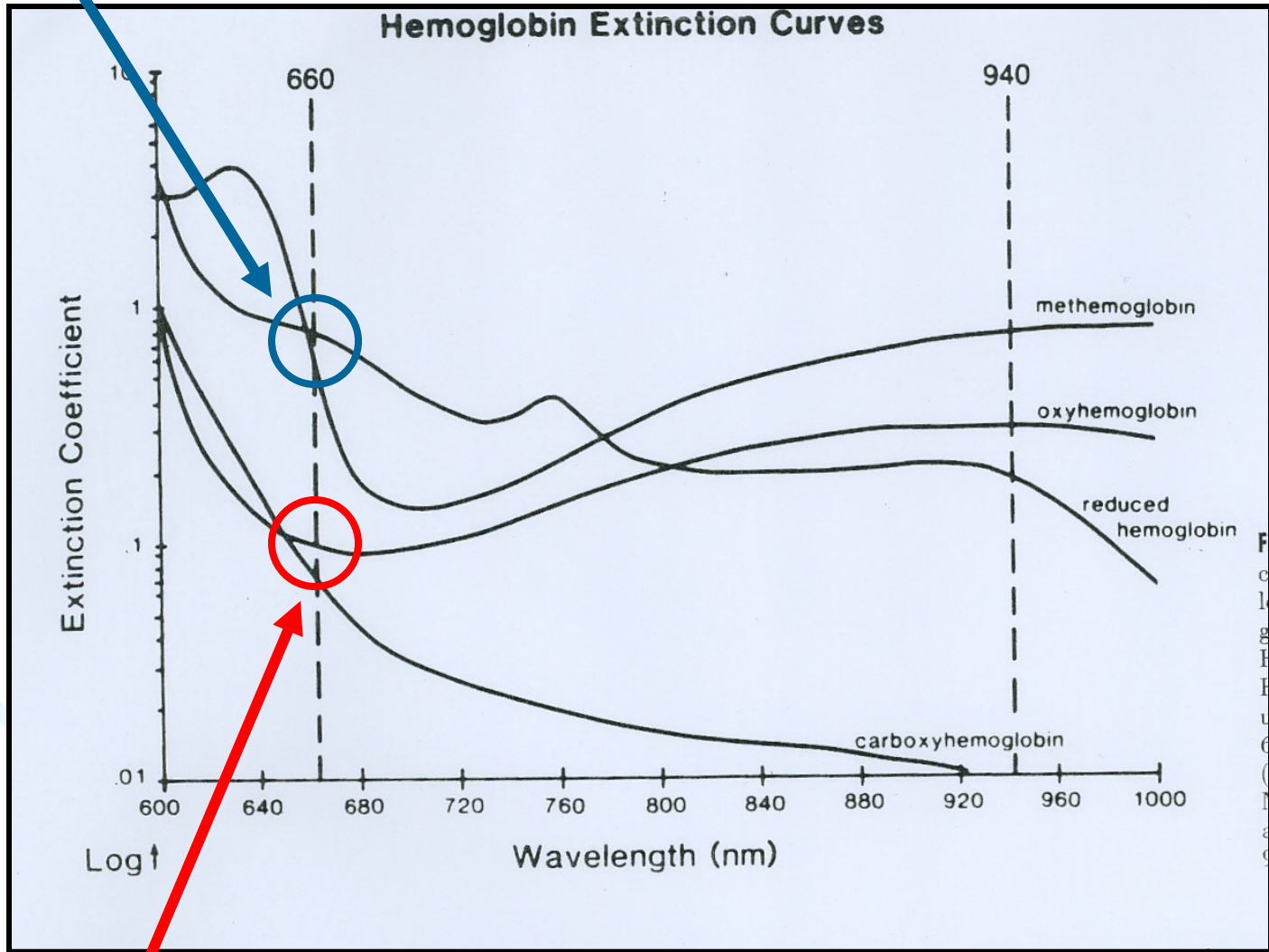




Functional vs Fractional

- Pulse ox yields **functional saturation**
 - Ratio of HgbO_2 to the sum of all functional hemoglobins (not CO-Hgb)
 - Sites filled/sites available for O_2 to stick
- **Fractional saturation** measured by co-oximetry by blood gas analysis
 - Ratio of HgbO_2 to the sum of all hemoglobins

Absorption characteristics falsely account for a low sat in the patient with Hgb-Met



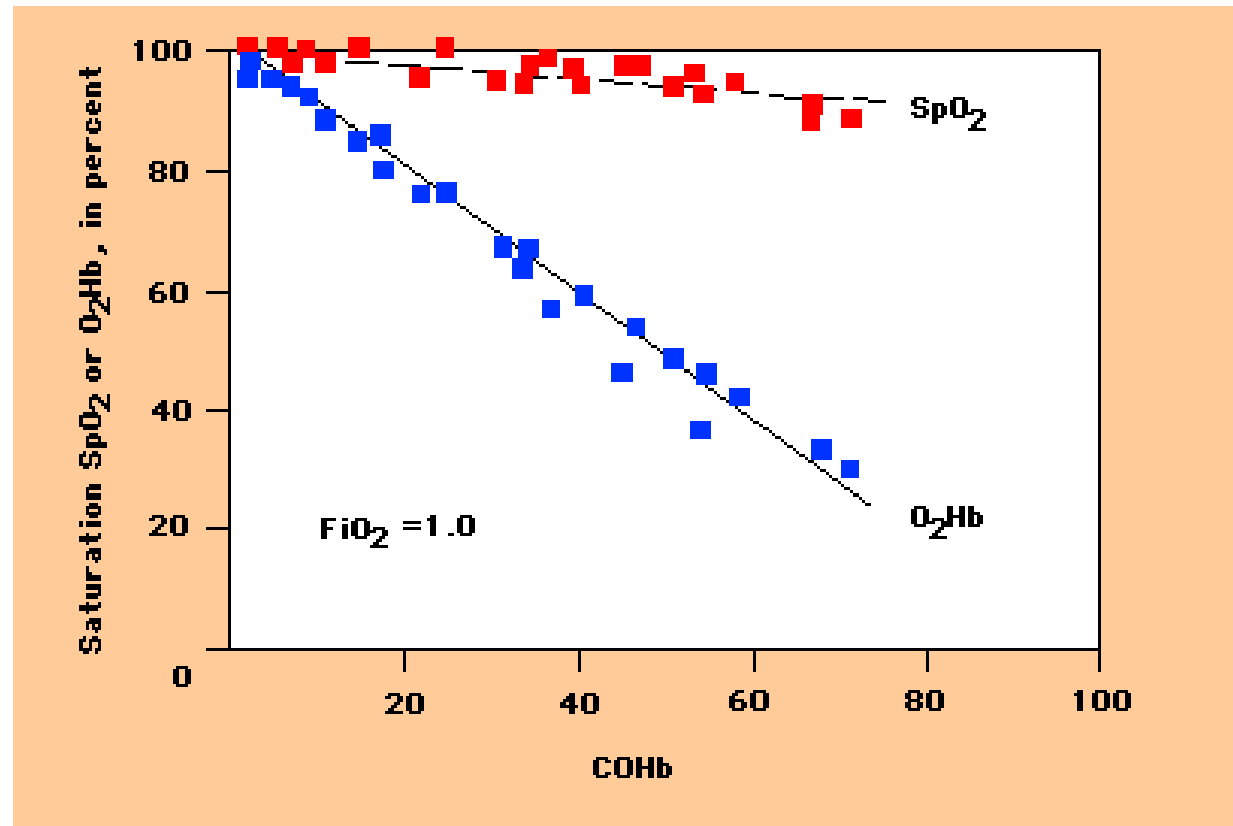
Hgb-CO & Hgb-O₂ have similar absorbance at 666nm so Hgb-CO will be falsely interpreted as Hgb-O₂ (high sat)



Pulse Oximetry- Confounders

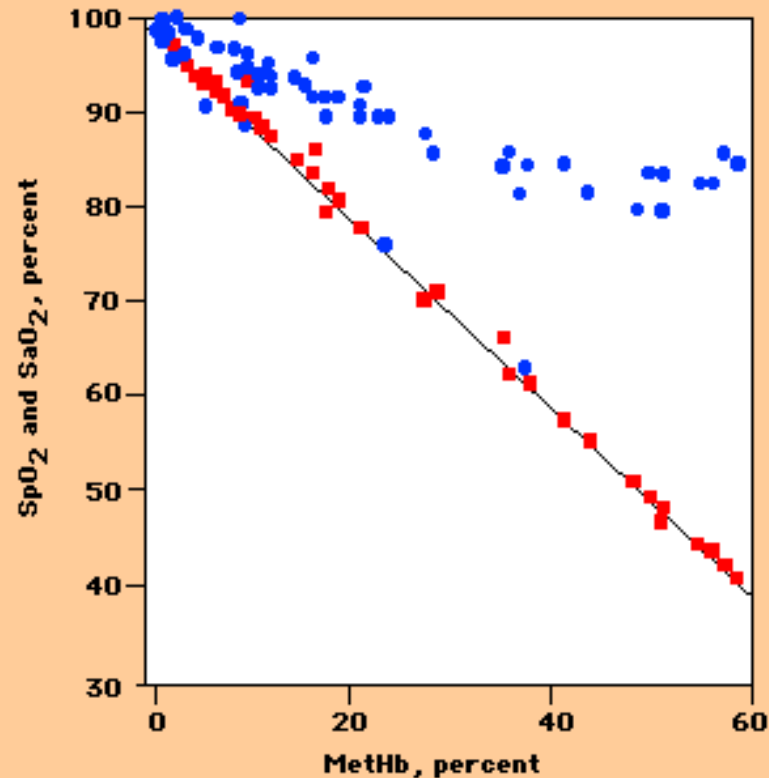
- Misses other Hgb species (Hgb-CO, Hgb-Met)
- Low perfusion states, severe edema or peripheral vascular disease make it difficult for the sensor to distinguish the true signal from background
- Increased venous pulsations causes overestimation of deoxyHgb & decreased sats
- Adversely affected by external light sources & motion artifact

CO-Hgb



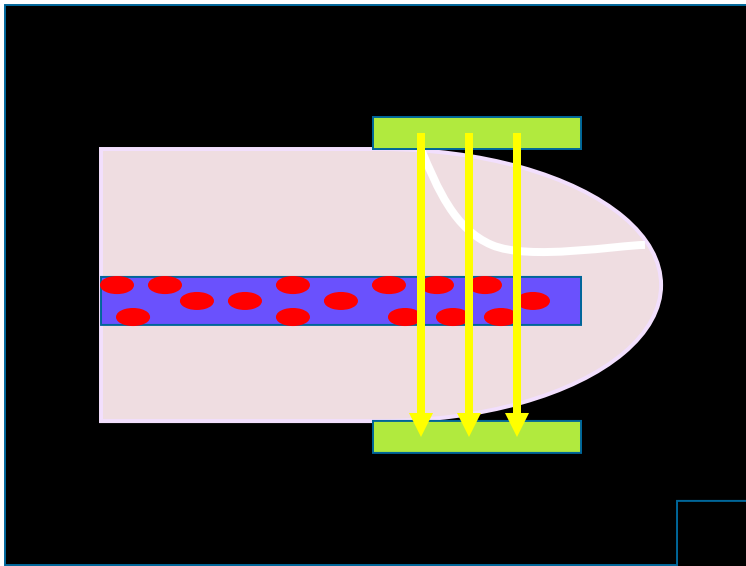
Effect of carboxyhemoglobin on measured oxygen saturation by pulse oximetry SpO₂ and O₂Hb versus carboxyhemoglobin (COHb) at $FiO_2 = 1.0$. SpO₂ consistently overestimates saturation in the presence of COHb. At COHb=70 percent, SpO₂ is still roughly 90 percent, while O₂Hb has fallen to 30 percent. Redrawn from Barker, SJ, Tremper, KK, Anesthesiology 1987; 66:677.

Met-Hgb

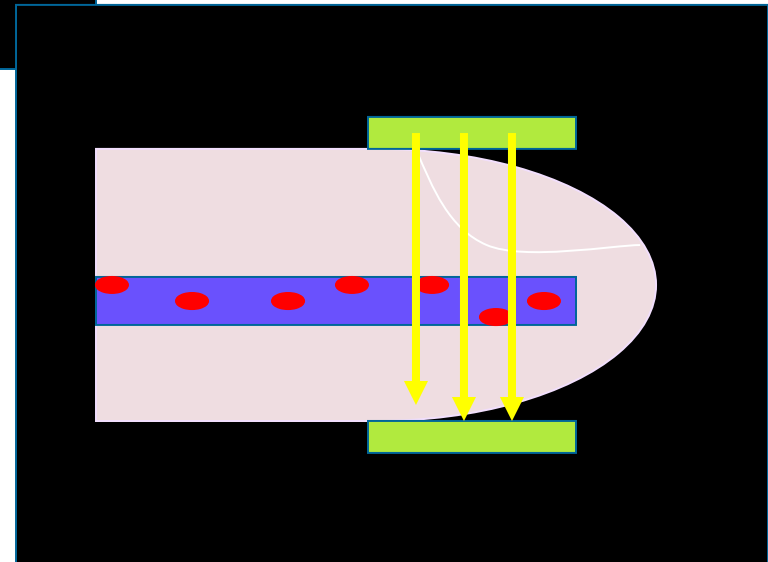


Effect of methemoglobin on measured oxygen saturation by pulse oximetry Nellcor SpO₂ reading (blue circles) and true SaO₂ (red squares) versus MethHb percent at FiO₂ = 1.0. Redrawn from Barker, SJ, Tremper, KK, Hyatt, J, Anesthesiology 1989; 70:112.

Pulse Oximetry - Anemia



Hgb 15, Sat 100%
Normal O₂ content



Hgb 8, Sat 100%
Decreased O₂ content
Until Hgb < 5, then
sampling errors

Transcutaneous

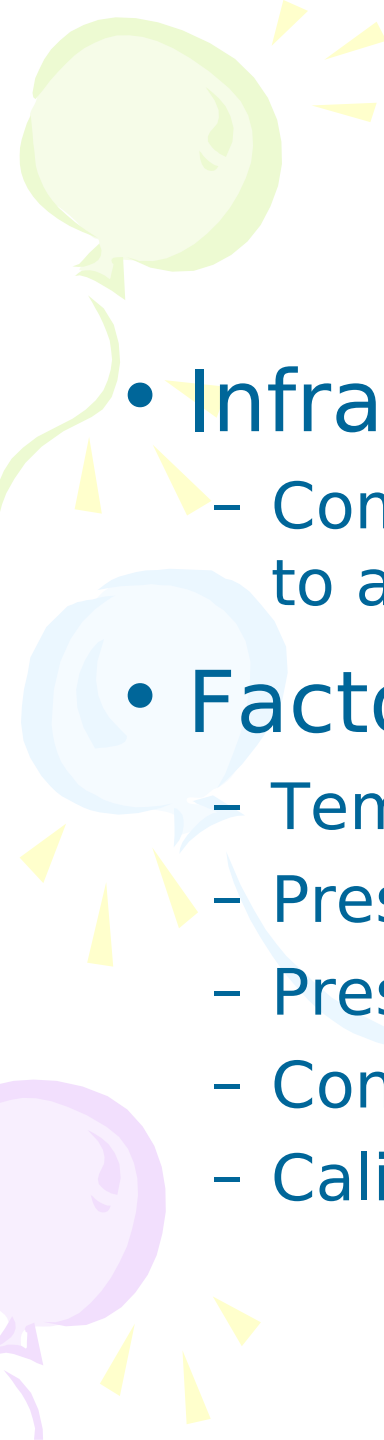


- Developed in late 1970's for use in neonates
- Electrode is placed on a well-perfused, non-bony surface, skin is warmed to 41-44°C to facilitate perfusion and allow diffusion of gases
- Estimates partial pressure of O₂ & CO₂
- Several studies demonstrated better oxygen correlation with pulse ox

CXR

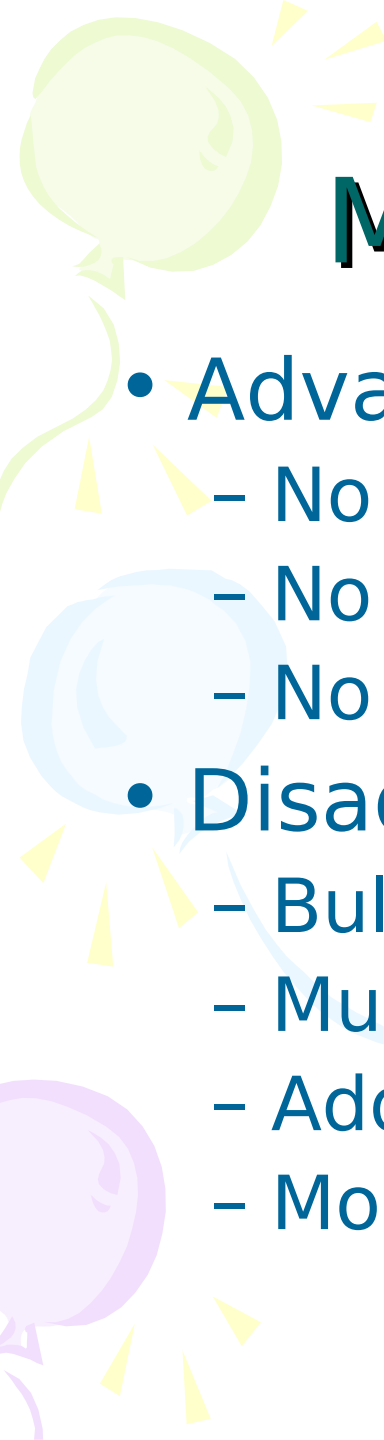
- Several studies in adults and pediatrics show significance of CXR to evaluate ETT or CVL location
- One peds study showed that CXR was more sensitive than PEx for detecting significant problems
- Consider routine use with infants or patients being prone





Capnography

- Infrared spectroscopy
 - Compares the amount of infrared light absorbed to amount in chamber with no CO₂
- Factors affecting :
 - Temp
 - Pressure
 - Presence of other gases
 - Contamination of sample chamber
 - Calibration



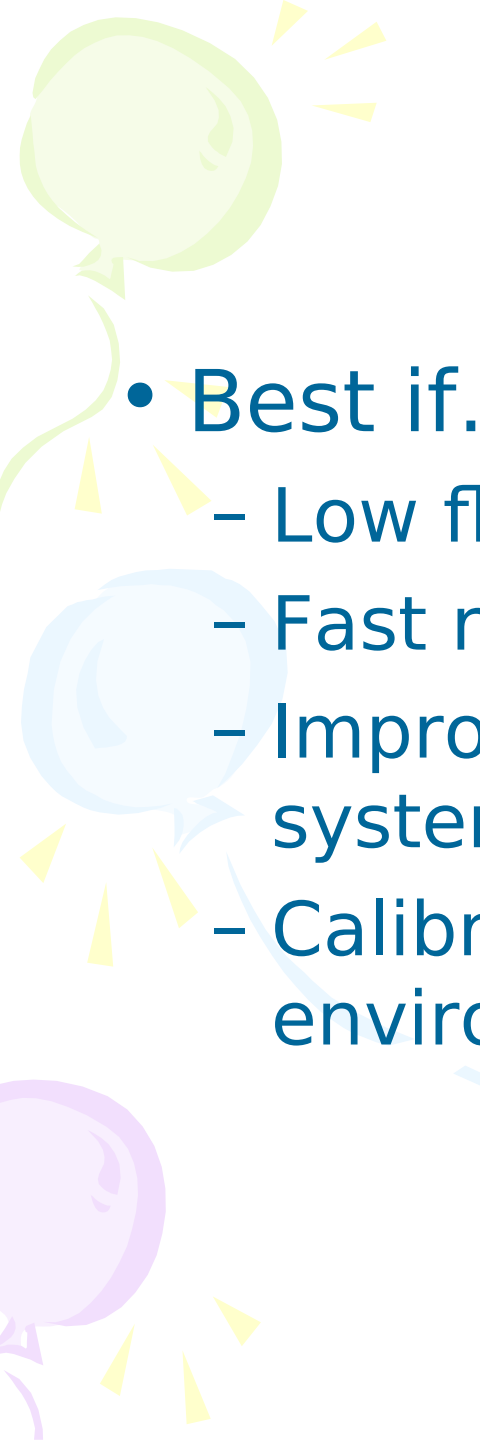
Capnography – Mainstream sampling

- Advantages:
 - No aspiration of liquid
 - No lag time
 - No mixing gases in sample tube
- Disadvantages:
 - Bulky airway adaptor
 - Must be intubated
 - Adds dead space
 - Moisture can contaminate chamber



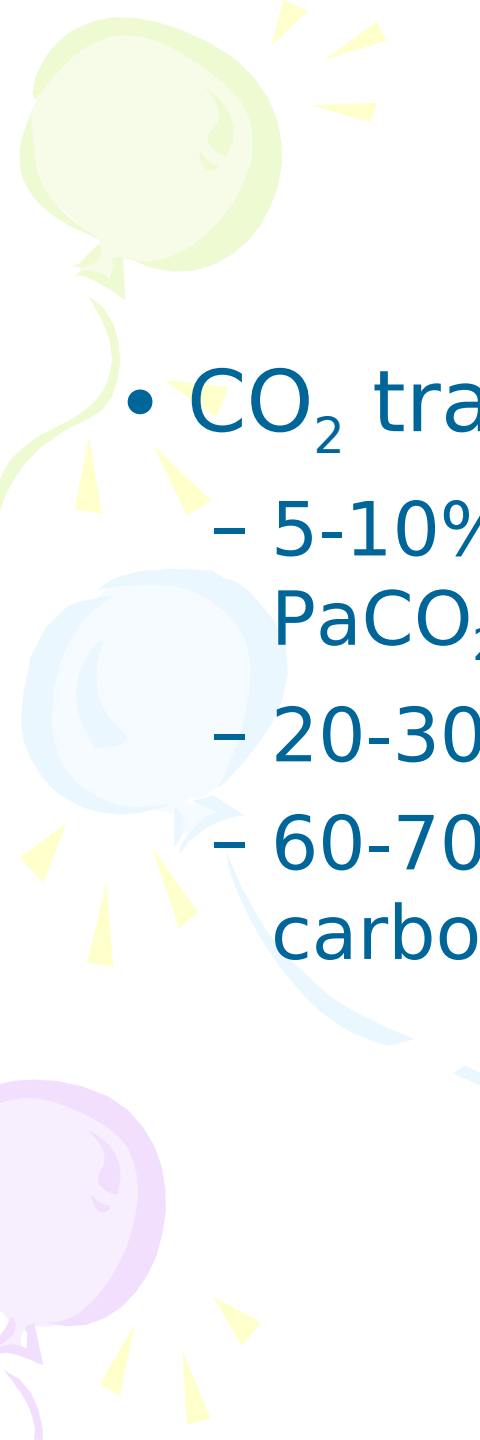
Capnography – Sidestream sampling

- Advantages:
 - Easier to calibrate
 - No added weight to airway
 - Less dead space
 - Less likely to become contaminated
- Disadvantages:
 - Lag time for transit of sample
 - If TV small or flow rate high, inhaled gas may be aspirated with exhaled gas



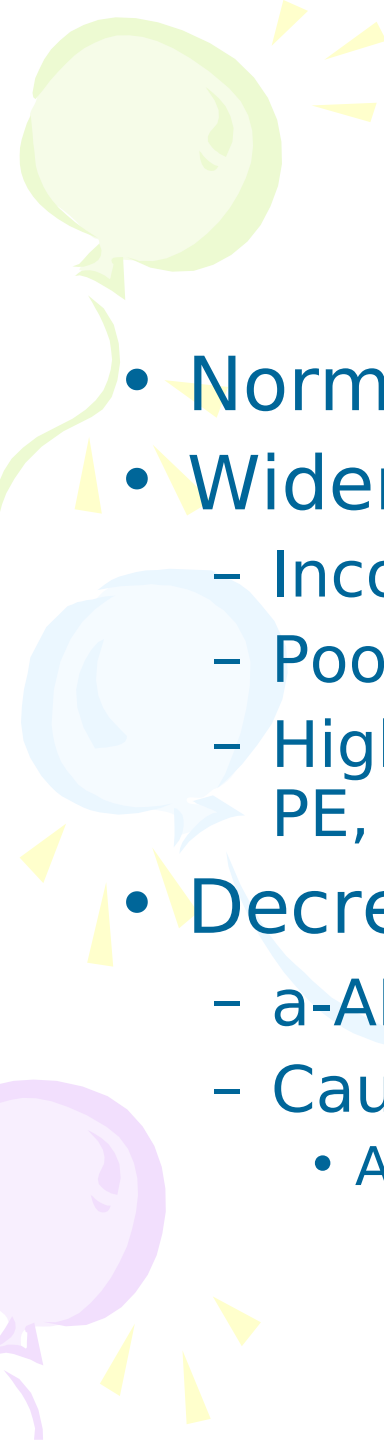
Capnography

- Best if...
 - Low flow sample rates
 - Fast response times
 - Improved moisture handling and purge systems
 - Calibration and correction for environmental factors



CO₂ Physiology

- CO₂ transported in blood
 - 5-10% carried in solution reflected by PaCO₂
 - 20-30% bound to Hgb & other proteins
 - 60-70% carried as bicarbonate via carbonic anhydrase



CO₂ Physiology

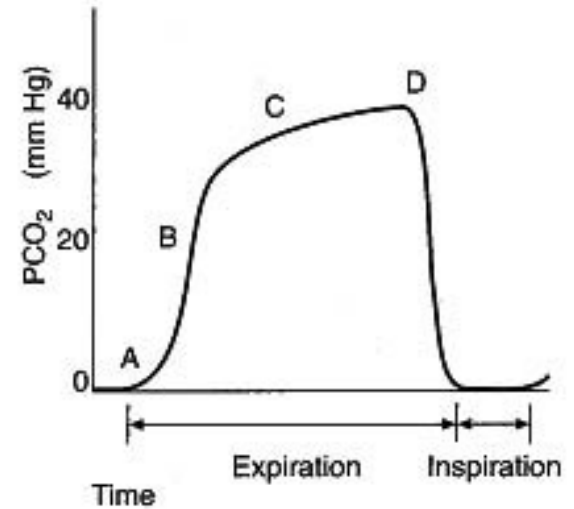
a-ADCO₂

- Normally 2-3mmHg
- Widened if
 - Incomplete alveolar emptying
 - Poor sampling
 - High VQ abnormalities (normal 0.8), seen with PE, hypovolemia, arrest, lateral decubitus
- Decreased with shunt
 - a-ADCO₂ small
 - Causes:
 - Atelectasis, mucus plug, right mainstem ETT

Capnograms

Normal

- Zero baseline
- Rapid, sharp uprise
- Alveolar plateau
- Well-defined end-tidal point
- Rapid, sharp downstroke

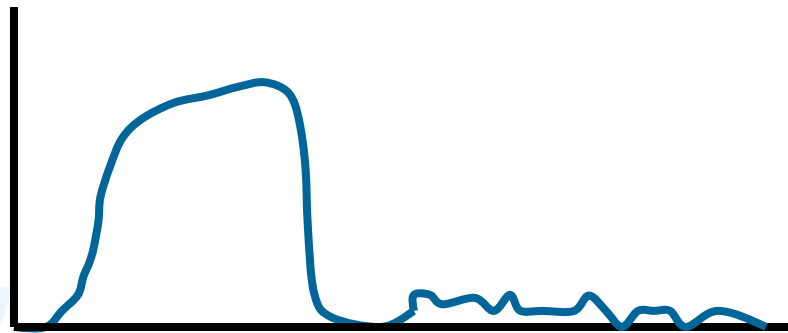


A—B	Deadspace
B—C	Dead space and alveolar gas
C—D	Mostly alveolar gas
D	End-tidal point
D—E	Inhalation of CO ₂ free gas

Capnography

Sudden loss of waveform

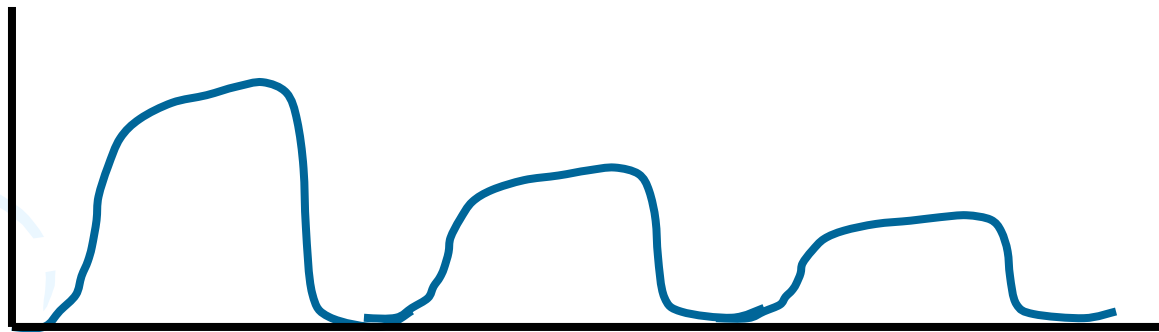
- Esophageal intubation
- Ventilator disconnect
- Ventilator malfunction
- Obstructed / kinked ETT



Capnography

Decrease in waveform

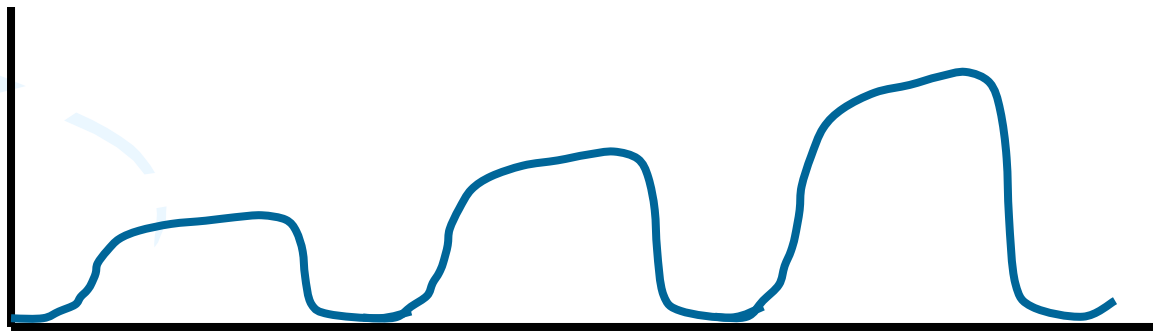
- Sudden hypotension
- Massive blood loss
- Cardiac arrest
- Hypothermia
- PE
- CPB



Capnography

Gradual increase in waveform

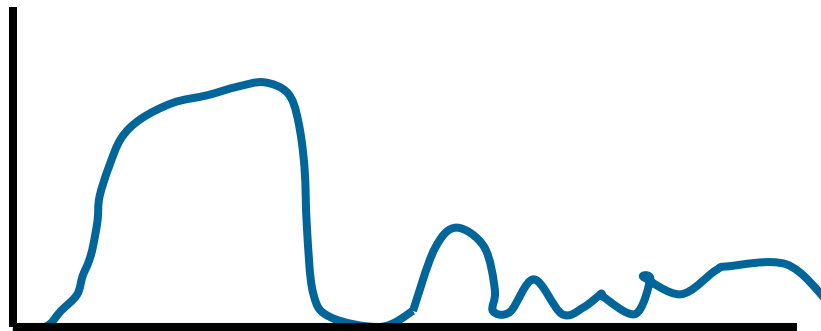
- Increased body temp
- Hypoventilation
- Partial airway obstruction
- Exogenous CO₂ source
(w/laparoscopy/CO₂ inflation)



Capnography

Sudden drop – not to zero

- Leak in system
- Partial disconnect of system
- Partial airway obstruction
- ETT in hypopharynx

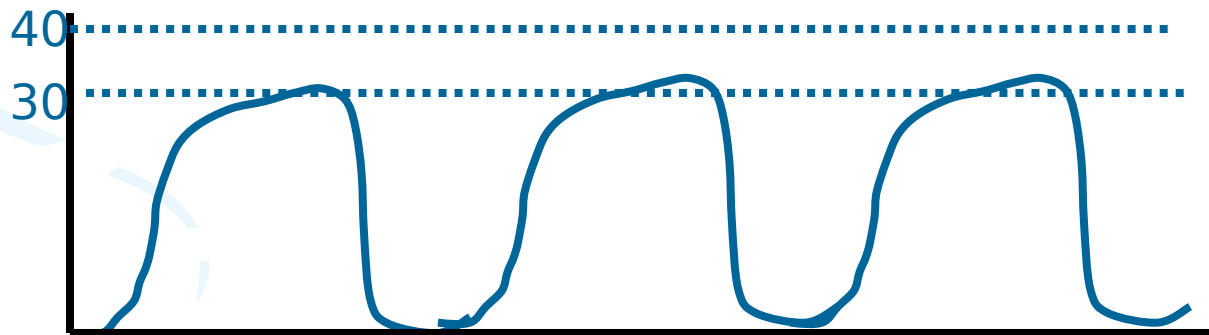


Capnography

Sustained low EtCO₂

- Asthma
- PE
- Pneumonia
- Hypovolemia
- Hyperventilation

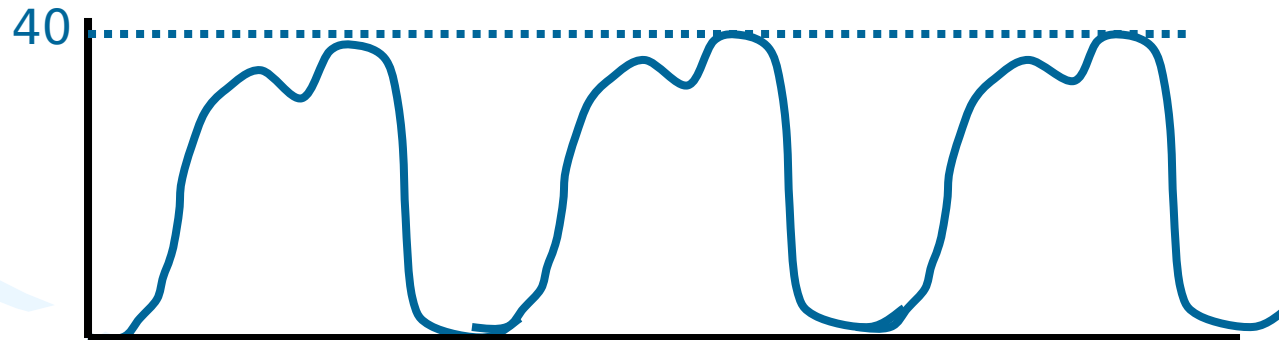
Low ETCO₂, but good plateau



Capnography

Cleft in alveolar plateau

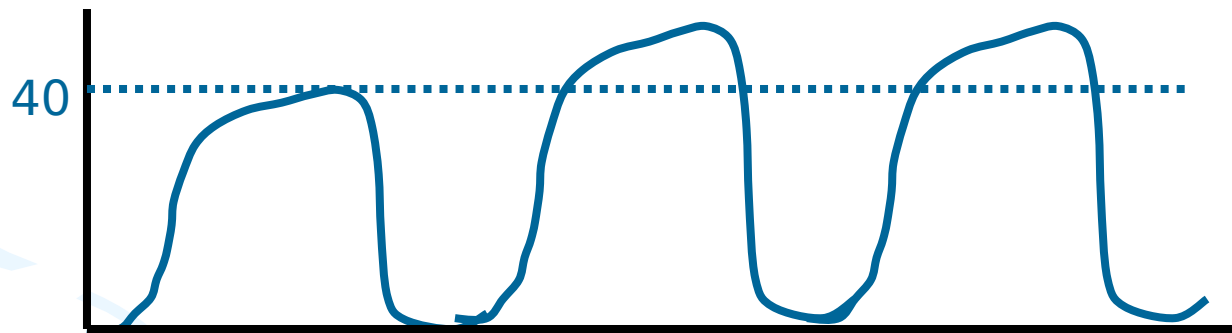
- Partial recovery from neuromuscular blockade



Capnography

Transient rise in ETCO_2

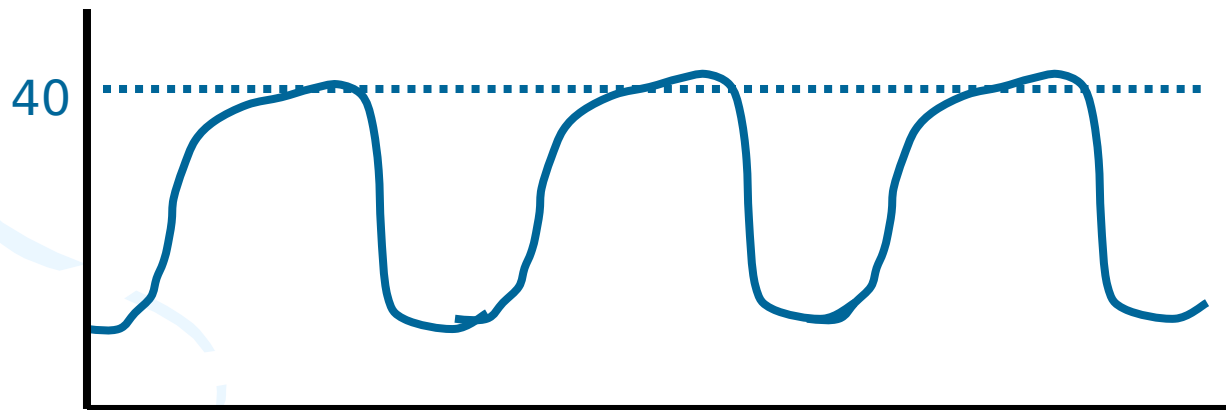
- Injection of bicarbonate
- Release of limb tourniquet

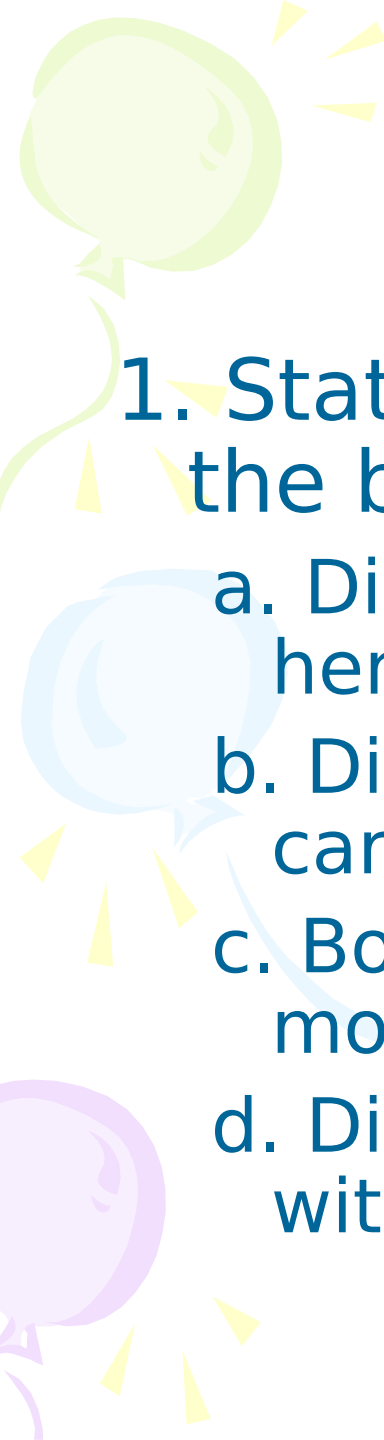


Capnography

Sudden rise in baseline

- Contamination of the optical bench – need to recalibrate

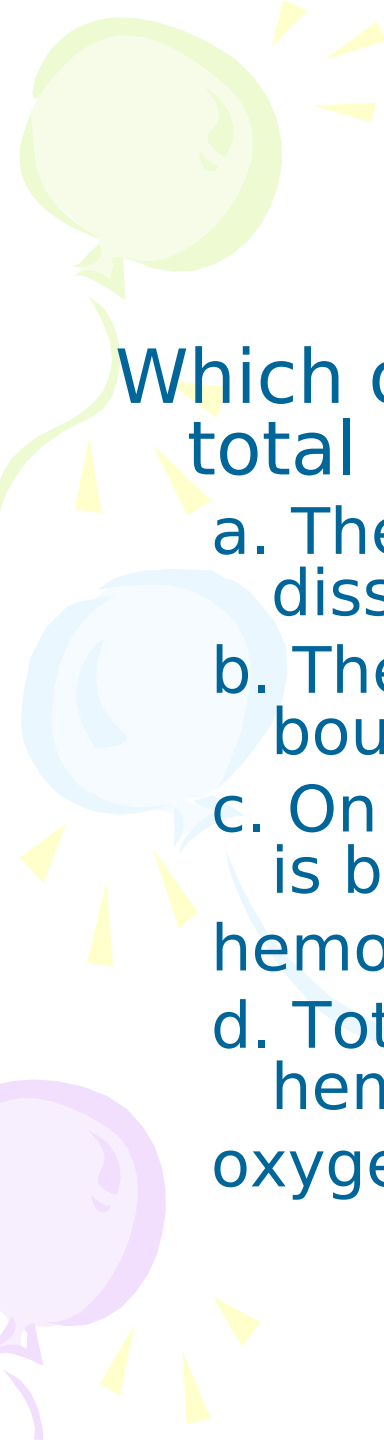




Question 1

1. State two ways oxygen is carried in the blood.

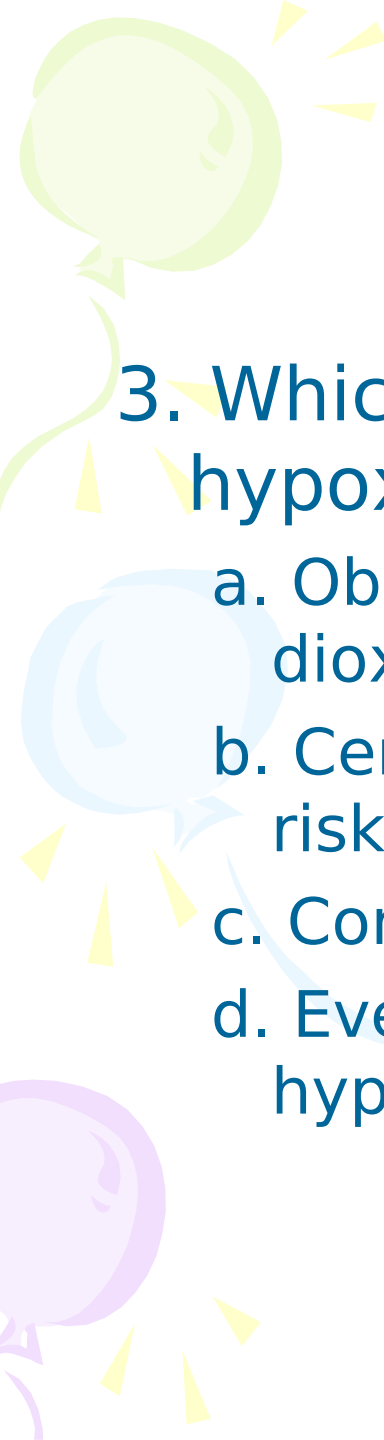
- a. Dissolved in plasma and bound with hemoglobin.
- b. Dissolved in plasma and bound with carboxyhemoglobin.
- c. Bound with hemoglobin and carbon monoxide.
- d. Dissolved in hemoglobin and bound with plasma.



Question 2

Which of the following statements about total oxygen content is true?

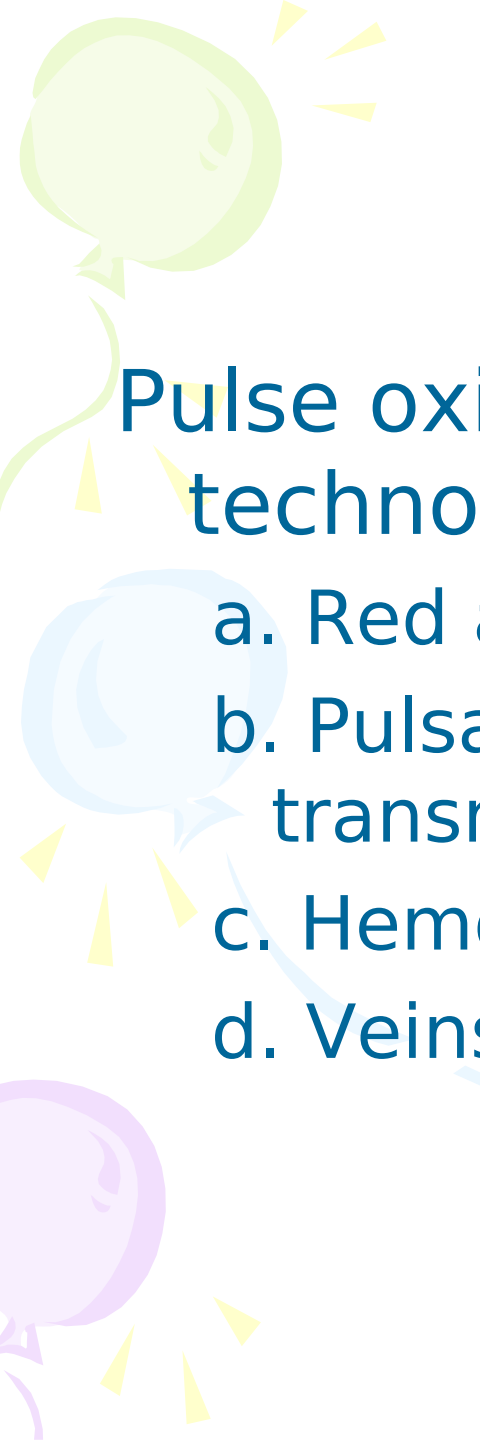
- a. The majority of oxygen carried in the blood is dissolved in the plasma.
- b. The majority of oxygen carried in the blood is bound with hemoglobin.
- c. Only 1% to 2 % of oxygen carried in the blood is bound with hemoglobin.
- d. Total oxygen content is determined by hemoglobin ability to release oxygen to the tissues.



Question 3

3. Which of the following statements about hypoxemia is false?

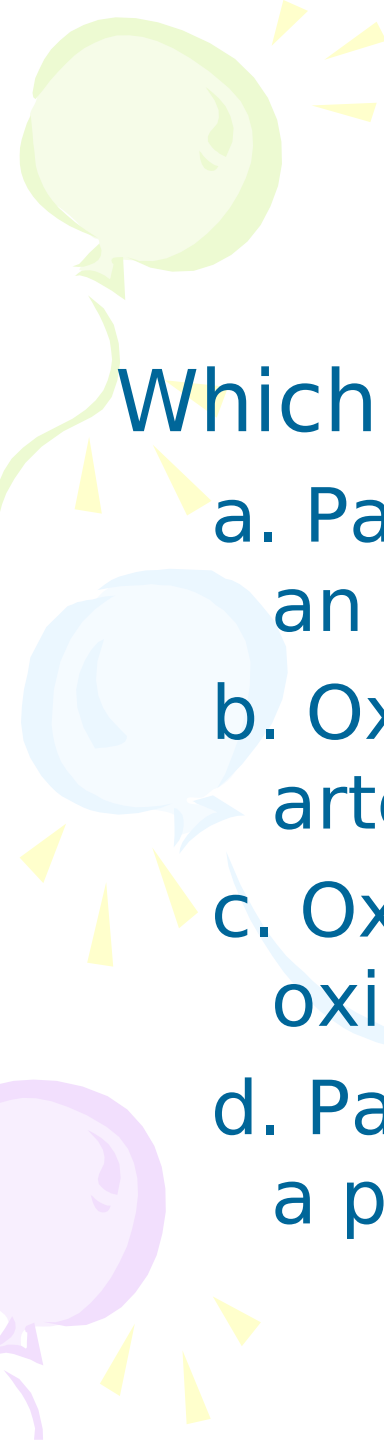
- a. Obstructive sleep apnea may cause carbon dioxide retention, but not hypoxemia.
- b. Certain postoperative patients are at greater risk for hypoxemia.
- c. Confusion may be a symptom of hypoxemia.
- d. Even the obstetric patient may be at risk for hypoxemia.



Question 4

Pulse oximetry incorporates two technologies that require:

- a. Red and yellow light.
- b. Pulsatile blood flow and light transmittance.
- c. Hemoglobin and methemoglobin.
- d. Veins and arteries.



Question 5

Which of the following defines “SpO2”?

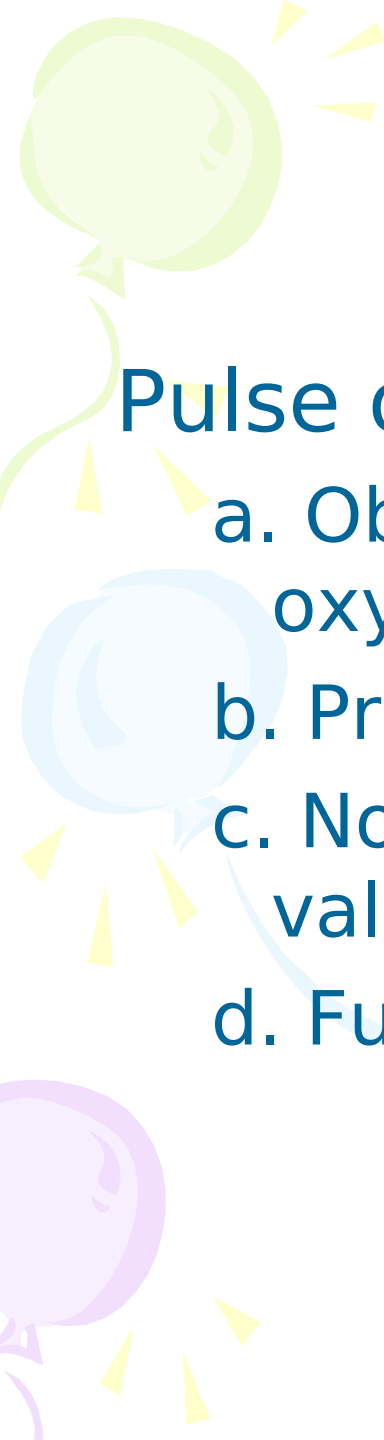
- a. Partial pressure of oxygen provided by an arterial blood gas.
- b. Oxygen saturation provided by an arterial blood gas.
- c. Oxygen saturation provided by a pulse oximeter.
- d. Partial pressure of oxygen provided by a pulse oximeter.



Question 6

If your patient's oxygen saturation has fallen from 98% to below 90%, after receiving 4 liters O₂ via nasal cannula, the following physiologic changes may be occurring:

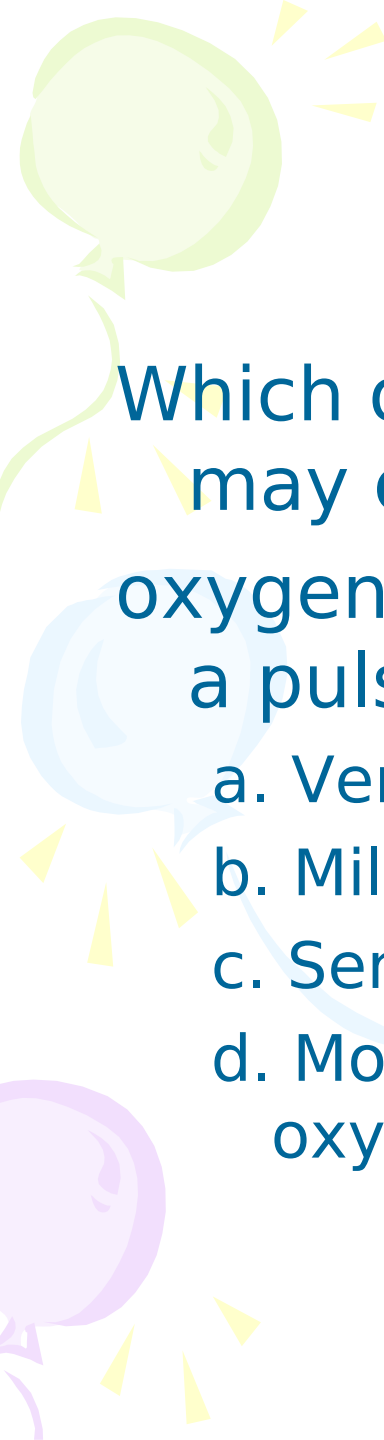
- a. Oxygen content is rapidly decreasing.
- b. PaO₂ level is rapidly increasing.
- c. Oxygen content is slowly decreasing.
- d. PaO₂ level is slowly increasing.



Question 7

Pulse oximetry can be used to:

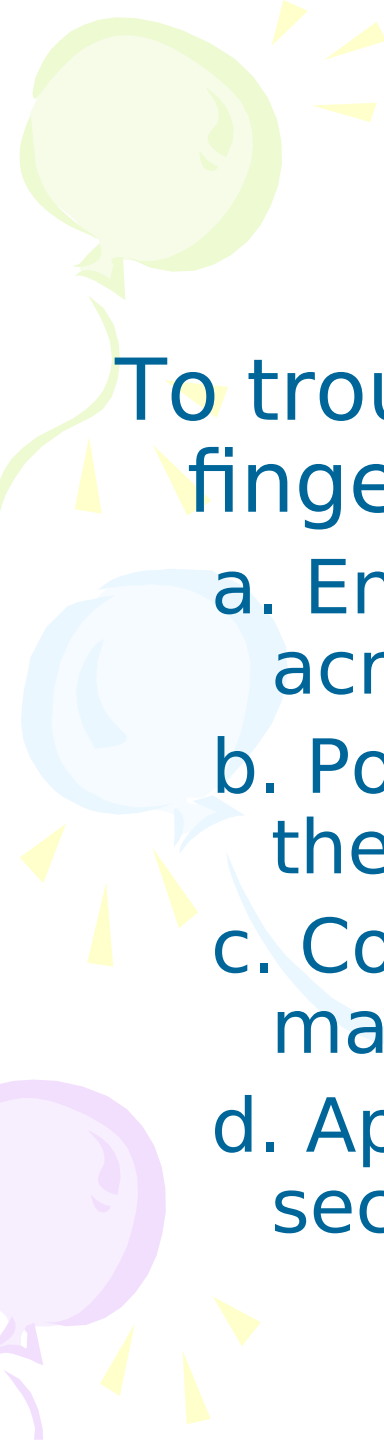
- a. Obtain invasive information about oxygenation.
- b. Provide acid-base profiles.
- c. Noninvasively monitor saturation values during ventilator weaning.
- d. Fully replace arterial blood gas testing.



Question 8

Which of the following clinical conditions may contribute to inaccurate oxygen saturation readings as measured by a pulse oximeter?

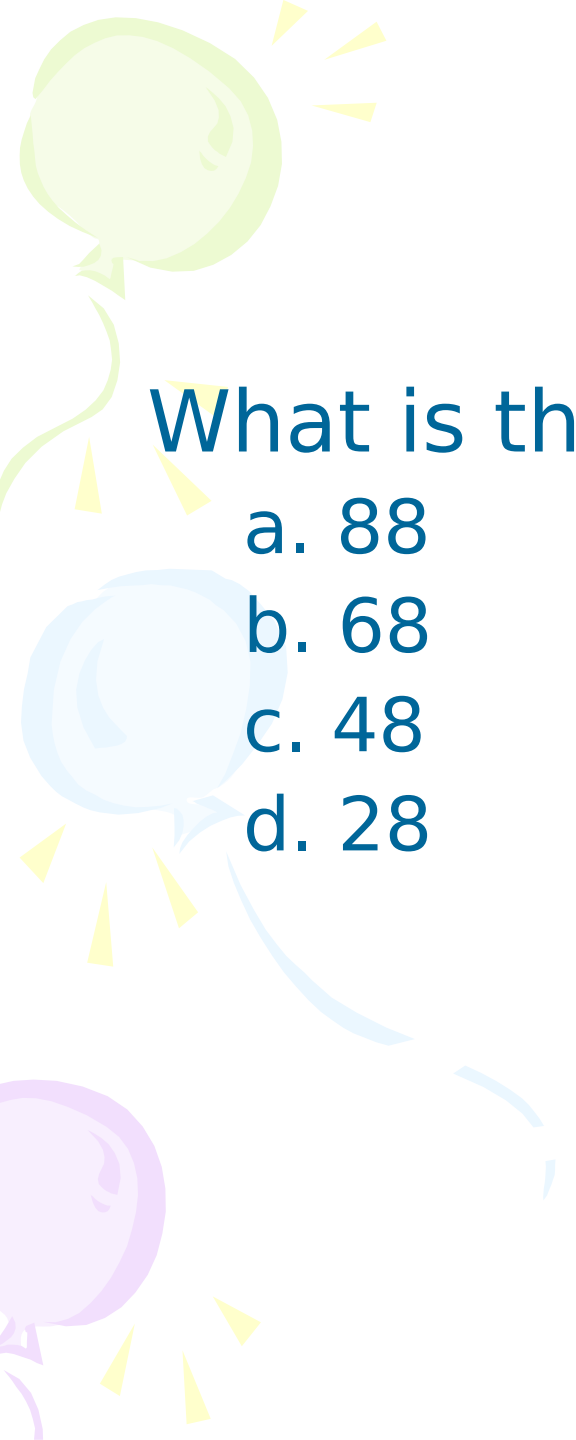
- a. Venous pulsations.
- b. Mild anemia.
- c. Sensor placed on a middle finger.
- d. Monitoring a patient during weaning from oxygen.



Question 9

To troubleshoot motion artifact on a finger or toe sensor:

- a. Ensure the light source is directly across from the photodetector.
- b. Position the sensor below the level of the heart.
- c. Cover the sensor with an opaque material.
- d. Apply additional tape to the sensor to secure it in place.



Question 10

What is the PaO₂ at 50% SpO₂?:

- a. 88
- b. 68
- c. 48
- d. 28