OXYGENATION AND ACID-BASE EVALUATION
Chapter 1
MECHANICAL VENTILATION

- Used when patients are unable to sustain the level of ventilation necessary to maintain the gas exchange functions
- Artificial support of lung function
- The Roman physician Galen may have been the first to describe mechanical ventilation: "If you take a dead animal and blow air through its larynx [through a reed], you will fill its bronchi and watch its lungs attain the greatest distention."
- Andreas Vesalius (founder of modern human anatomy) also describes ventilation by inserting a reed or cane into the trachea of animals.
INDICATIONS

- Ventilatory Failure
- Oxygenation Failure
- Failure of both oxygenation and ventilation
- Pathophysiological Factors
  - Increased airway resistance
  - Changes in lung compliance
  - Hypoventilation
  - V/Q mismatch
  - Intrapulmonary shunting
  - Diffusion defect
VENTILATION DELIVERY

- **Performed by:**
  - Hand
  - Machine

- **Available for:**
  - Short term
  - Long term
  - Acute care
  - Extended home care

- **Interface**
  - ETT
  - Tracheostomy
  - Mask
  - LMA
GAS EXCHANGE
ARTERIAL BLOOD GAS REVIEW

- Provides valuable information about a patient’s oxygenation, ventilation, and acid-base status
- Vital part of the assessment and management of a mechanically ventilated patient
- Should be used with caution – represents one point in time
- A series of ABG results should be compared to see if “trends” are present
- Avoid excessive or curiosity sampling
- Interpretation in the context of the clinical setting/patient status
OXYGENATION

- \( \text{PaO}_2 \)
- \( \text{SaO}_2 \)
- \( \text{CaO}_2 \)
- \( P_{(A-a)}\text{O}_2 \)
- \( \text{PvO}_2 \)
- \( C(a-\tilde{v})\text{ O}_2 \)
- \( \dot{\text{VO}}_2 \)
- \( \text{DO}_2 \)
- \( \dot{Q}_s/\dot{Q}_t \)
A 40 year old patient has a P(A-a)O2 of 15mmHg. Is this in the normal range for this patient?

At age 20 the normal P(A-a)O2 is about 5mmHg; it increases 4mmHg per decade. At age 40 this would represent an increase of 8mmHg or a value of 13mmHg. The value of 15 is reasonably close to normal.
LOW OXYGEN LEVELS:

- Hypoxia
  - Lower than normal oxygen pressure in the tissues or alveoli
  - Types/Causes
    - Hypoxemic
    - Anemic
    - Circulatory/stagnant
    - Histotoxic
    - Affinity

- Hypoxemia
  - Low arterial blood oxygen pressure
  - Causes
    - Hypoventilation
    - Decreased PiO₂
    - Shunt
    - Diffusion defects
    - Poor distribution of ventilation
TRANSFER AND UPTAKE OF $O_2$ FROM THE ALVEOLI

$P_{(A-a)O_2}$:
- ability of lungs to bring in and transfer oxygen
- Increased gradient demonstrates a decreased transfer, due to:
  - Age
  - Lung disease
  - V/Q mismatch
  - Shunt
  - Diffusion defects
TRANSFER AND UPTAKE OF $O_2$ FROM THE ALVEOLI

$PaO_2/P_{A}O_2$: 
- fraction of oxygen that is transferred to the artery
- Stable with changes in $FiO_2$
- Normal 0.9 (90%)
- Less than 75% indicates a problem
TRANFER AND UPTAKE OF O₂ FROM THE ALVEOLI

\( \text{PaO}_2 / \text{FiO}_2 \): 
- P to F ratio
- Amount of oxygen moving into the blood in relation to the inspired oxygen
- Used to describe the degree of lung injury
- Normal 380-476mmHg
- Lower values indicate disorders
  - <200 ARDS
  - 200-300 ALI
OXYHEMOGLOBIN DISSOCIATION CURVE

- S-shaped curve, relationship of plasma PO$_2$ and O$_2$ bound to Hb (SO$_2$)
- Flat portion: minor changes in PO$_2$ have little effect on SO$_2$
  Strong Affinity!
- Steep portion: small drop in PO$_2$ causes a large drop in SO$_2$
  Weak Affinity!
OXYGEN CONTENT AND OXYGEN DELIVERY

- Together these determine the amount of oxygen available for utilization at the tissues
- Considers oxygen, hemoglobin and cardiac output
- $\text{CaO}_2 = (1.34 \times \text{Hb} \times \text{SaO}_2) + (\text{PaO}_2 \times 0.003)$
- $\text{DO}_2 = \text{CaO}_2 \times \text{CO}$
A patient has a measured PaO$_2$ of 80mmHg and an SaO$_2$ of 97%. The Hb is 10gm%. Does this patient have a normal oxygenation status?

Although the PaO$_2$ and SaO$_2$ are normal, the low hemoglobin will cause a reduction in this patient’s CaO$_2$. Therefore this patient does not have a normal oxygenation status.
ALVEOLAR VENTILATION

- Normal: 4-5L/min
- $V_A = V_t - V_D$
- $\dot{V}_A = (V_t - V_D) \times f$
- $\uparrow \dot{V}_A = \downarrow \text{PaCO}_2$, $\uparrow \text{PaO}_2$
  - Hyperventilation
- $\downarrow \dot{V}_A = \uparrow \text{PaCO}_2$, $\downarrow \text{PaO}_2$
  - Hypoventilation
- Alveolar air equation
- As $\text{PaCO}_2 \uparrow$ by 1mmHg, $\text{PaO}_2 \downarrow$ by 1.25mmHg
A patient has a PaO$_2$ of 50mmHg and a PaCO$_2$ of 80mmHg. If the PaCO$_2$ were to decrease to a normal of 40mmHg, what would you expect the PaO$_2$ to be after the change (assuming the PaO$_2$ changes were due to the PaCO$_2$ changes alone and not to lung pathology)

A change in PaCO$_2$ from 80 to 40mmHg is a 40 mmHg difference; 40 X 1.25 = 50mmHg. The PaO$_2$ would be expected to increase by about 50mmHg to approximately 100mmHg.
\[ \text{PaCO}_2 = \frac{\dot{\text{VCO}}_2 \times 0.863}{\dot{V}_A} \]

Relationship between the amount of CO\textsubscript{2} produced from cellular metabolism and how well the CO\textsubscript{2} is removed from the lungs
HENDERSON-HASSELBALCH EQUATION

- Simplified to: \( H^+ = \frac{24 \times PaCO_2}{HCO_3^-} \)
  - Requires knowing the hydrogen ion concentration for a given pH
- Verification of pH/PaCO\(_2\) relationship
  - Buffers make it more difficult for the blood to become acidotic, CO\(_2\) must increase more to change the pH than compared to how much it decreases to raise the pH
A patient has a PaCO$_2$ of 78mmHg and a pH of 7.20. What would be an estimate of the patient’s bicarbonate level?

\[
\text{HCO}_3^- = \frac{24 \times 78}{65} = 28.8 \text{ mEq/L}
\]
ABG INTERPRETATION

- Degree of compensation
- Acid-base balance
- Cause: respiratory, metabolic, mixed
- Oxygenation – degree of hypoxemia
- Must interpret in the context of the clinical picture!!
  - Requires ventilation status
  - History, signs, symptoms
- Acute changes versus chronic