# 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

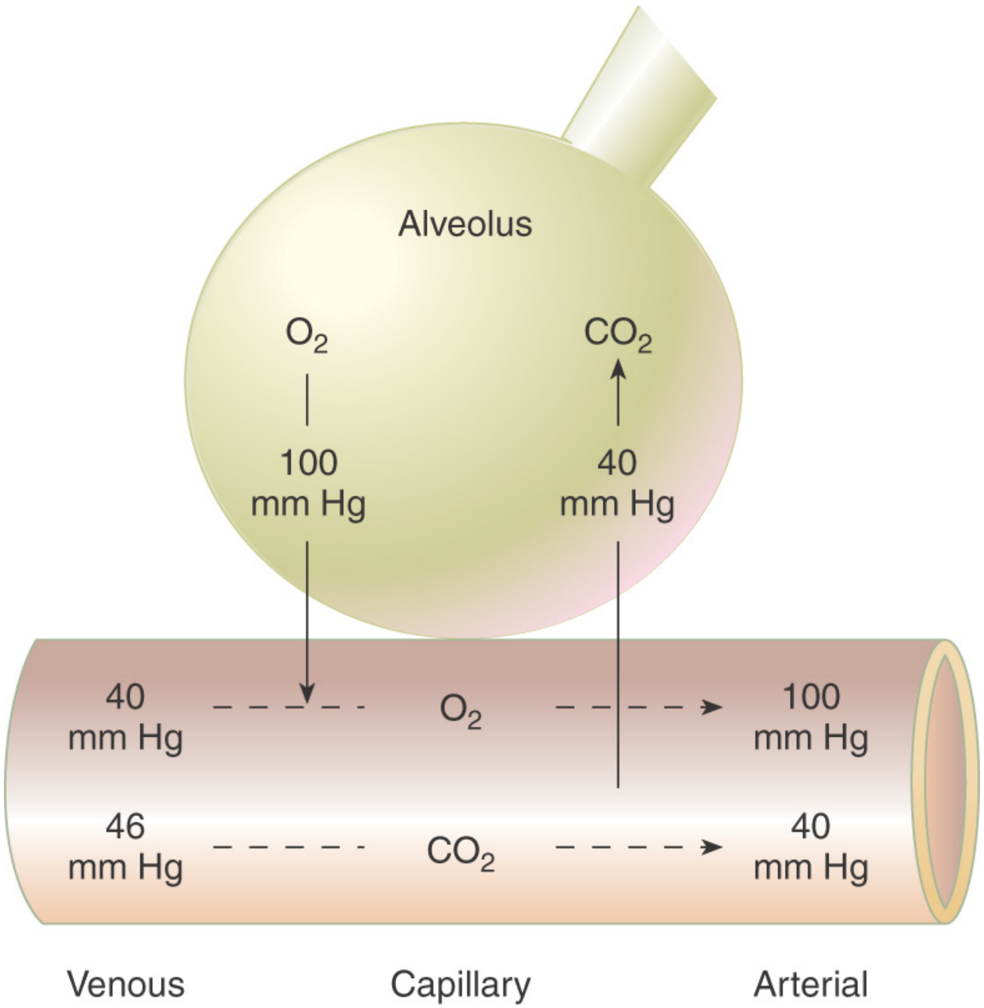
# VENTILATION DELIVERY

- Performed by:
  - Hand

  - Machine

- Available for:
  - Short term
  - Long term
  - Acute care
  - Extended home care
- Interface
  - ETT
  - Tracheostomy
  - Mask
  - LMA

# GAS EXCHANGE

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# 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

- $PaO_2$
- $SaO_2$
- $CaO_2$
- $P_{(A\text{-}a)}O_2$
- $P\bar{v}O_2$
- $C(a\text{-}\bar{v})\ O_2$
- $\dot{V}O_2$
- $DO_2$
- $\dot{Q}s/\dot{Q}t$

# Clinical Rounds 1-1

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 $PiO_2$
    - Shunt
    - Diffusion defects
    - Poor distribution of ventilation

# TRANSFER AND UPTAKE OF $O_2$ FROM THE ALVEOLI

## $P_{(A\text{-}a)}O_2$:

- 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

## $PaO_2/P_AO_2$:

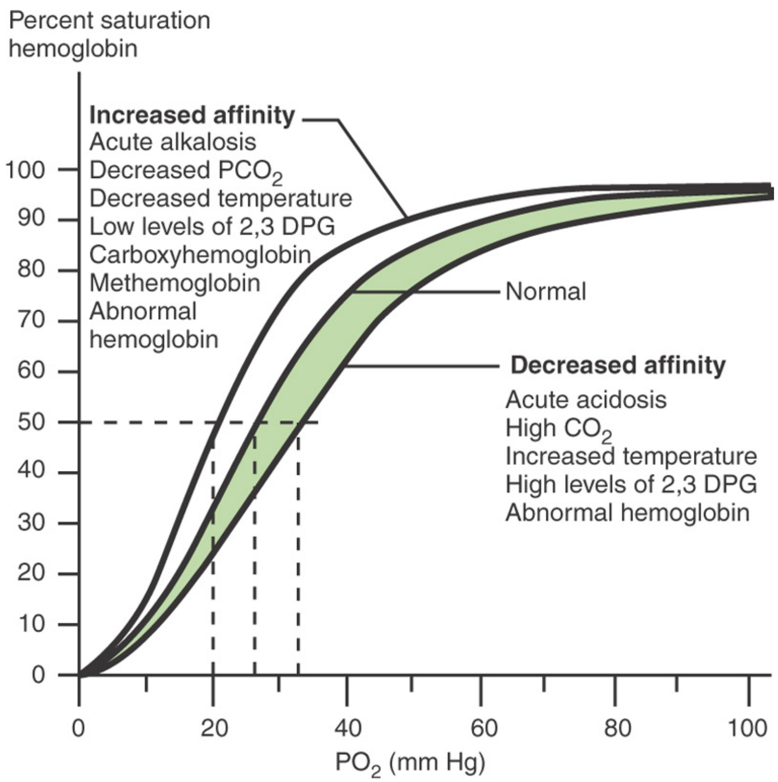
- fraction of oxygen that is transferred to the artery
- Stable with changes in $FiO_2$
- Normal 0.9 (90%)
- Less than 75% indicates a problem

# TRANSFER AND UPTAKE OF $O_2$ FROM THE ALVEOLI

## $PaO_2 / FiO_2$:

- 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




(Redrawn from Lane EE, Walker JF: *Clinical arterial blood gas analysis*, St Louis, 1987, Mosby.)

- 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
- $CaO2 = (1.34xHbxSaO2) + (PaO2x0.003)$
- $DO2= CaO2xCO$

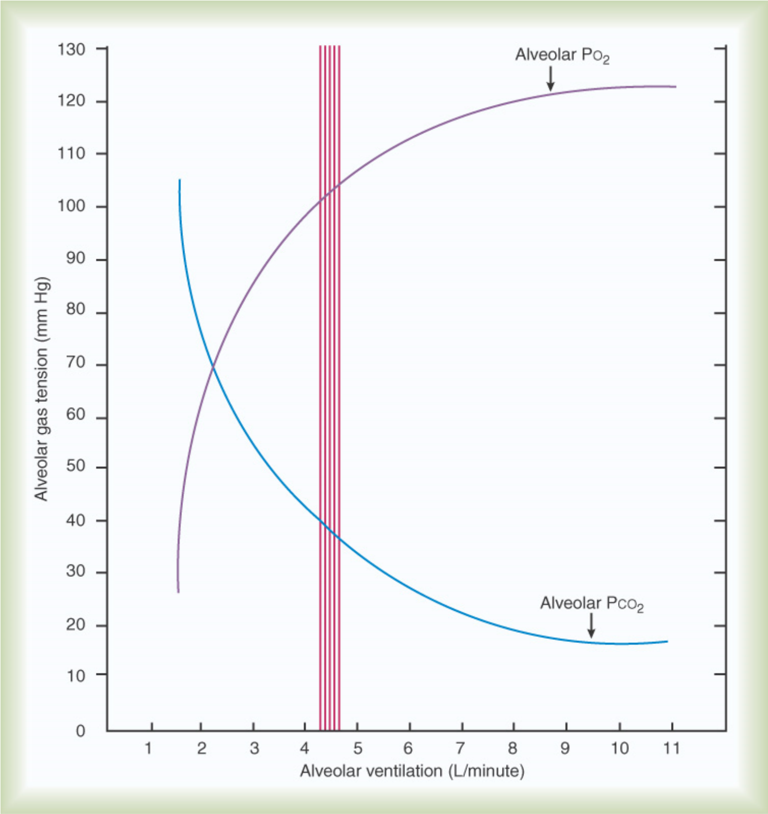
# CLINICAL ROUNDS 1-2

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
- $V_A = Vt - V_D$
- $\dot{V}_A = (Vt - V_D) \times f$
- $\uparrow \dot{V}_A = \downarrow PaCO_2, \uparrow PaO_2$
  - Hyperventilation
- $\downarrow \dot{V}_A = \uparrow PaCO_2, \downarrow PaO_2$
  - Hypoventilation
- Alveolar air equation
- As $PaCO_2 \uparrow$ by 1mmHg, $PaO_2 \downarrow$ by 1.25mmHg




(Modified from Pilbeam SP: Mechanical ventilation, ed 4, St Louis, 2006, Mosby.)

# CLINICAL ROUNDS 1-3

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.

$$PaCO_2 = \frac{\dot{V}CO_2 \times 0.863}{\dot{V}_A}$$

Relationship between the amount of $CO_2$ produced from cellular metabolism and how well the $CO_2$ is removed from the lungs

# HENDERSON-HASSELBALCH EQUATION

- Simplified to : $H^+ = \dfrac{24 \times PaCO_2}{HCO_3^-}$
  - 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

# CLINICAL ROUNDS 1-4

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?

$$HCO_3^- = \frac{24 \times 78}{65} = 28.8$$

29mEq/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