Interpretation of Blood Gases

Chapter 7
Precise measurement of the acid-base balance of the lungs’ ability to oxygenate the blood and remove excess carbon dioxide.
Arterial Blood Sampling

- Analyzing arterial blood samples is an important part of diagnosing and treating patients with respiratory failure.
- The radial artery is most often used because:
  - It is near the surface and easy to stabilize.
  - Collateral circulation usually exists (confirmed with the modified Allen’s test).
  - No large veins are near.
  - Radial puncture is relatively pain free.
Assessment of collateral circulation before radial artery sampling. **A**, Patient clenches fist while examiner obstructs radial and ulnar arteries. **B**, Patient gently opens hand while pressure is maintained over both arteries. **C**, Pressure over ulnar artery is released, and changes in color of patient’s palm are noted. (From Wilkins RL, Stoller JK, Scanlan CL: Egan’s fundamentals of respiratory care, ed 8, St Louis, 2003, Mosby.)
Sites of arterial punctures

- Brachial A.
- Radial A.
- Ulnar A.
- Femoral A.
- Inguinal ligament
- Posterior tibial A.
- Dorsalis pedis A.
ABG Processing

- Obtain sample without exposure to the environment
- Air bubbles should be removed
- Store sample on ice to inhibit metabolism
- Proper care of the puncture site
- Analyzed within 1 hour with properly calibrated and maintained equipment
Indications

- Acute shortness of breath/tachypnea
- Chest pain
- Hemoptysis
- Cough, fever and sputum production consistent with pneumonia
- Headache
- Past medical history
- Abnormal breath sounds
- Cyanosis

- Heavy use of accessory muscles
- Unexplained confusion
- Evidence of chest trauma
- Severe electrolyte abnormalities
- Changes in ventilator settings
- CPR
- Abnormal chest radiograph
ABG’s Evaluate

- Acid-Base Balance
  - pH, PaCO$_2$, HCO$_3^-$, BE
- Oxygenation Status
  - PaO$_2$, SaO$_2$, CaO$_2$, PvO$_2$
- Adequacy of ventilation
  - PaCO$_2$
Assessment of Oxygenation

- Measurements must be evaluated to identify the quantity of oxygen transported in the blood
- Tissue oxygenation status must be determined
Oxygen

In the blood:
- Oxygen bound to hemoglobin: \( \text{SaO}_2 \)
- Dissolved gas in the plasma: \( \text{PaO}_2 \)
- Total content of oxygen in the arterial blood: \( \text{CaO}_2 \)
**\( P_{aO_2} \)**

- normal values: 75-95mmHg
- Reflects the ability of the lungs to allow the transfer of oxygen from the environment to the circulating blood

- Normal predicted values depends on:
  - Barometric pressure
  - Patient’s age
  - \( FiO_2 \)
Alveolar air equation

\[ P_{A\text{O}_2} = F_i\text{O}_2 (P_B - P_{H2O}) - (P_{a\text{CO}_2} \times 1.25) \]

\[ P_{i\text{O}_2} = F_i\text{O}_2 (P_B - P_{H2O}) \]
HYPOXEMIA ≠ HYPOXIA

- HYPOXEMIA
- HYPOXIA
Hypoxemia

\[ P_{aO_2} \]

- 80-100 mmHg = normal
- 60-79 mmHg = mild hypoxemia
- 40-59 mmHg = moderate hypoxemia
- <40 mmHg = severe hypoxemia

**Causes**

- V/Q mismatch
  - Mucus plugging
  - Bronchospasm
- Diffusion defects
- Hypoventilation
- Low \( P_{iO_2} \)
SaO₂

- normal = 95-100%
- Index of the actual amount of oxygen bound to hemoglobin
- Determined from a co-oximeter

- Body temperature
- Arterial pH
- PₐCO₂
- Abnormal Hb
$\text{CaO}_2$

- normal = 16-20 vol%
- Significantly influences tissue oxygenation
- $(1.34 \times \text{Hb} \times \text{SaO}_2) + (P_a\text{O}_2 \times 0.003)$
- Reductions due to:
  - Anemia
  - Abnormal Hb
\[ P_{\text{A-aO}_2} \]

- Normal = 10-15 mmHg on Room Air
- Pressure difference between the alveoli and arterial blood
- Predicted normal depends on
  - Age
  - \( F_iO_2 \)
- Estimate for patients on room air = age x 0.4

- Increased gradient = respiratory defects in oxygenation ability
- Hypoxemia with a normal A-a gradient
  - Primary hyperventilation
  - High altitudes
\( P_vO_2 \)

- Normal value 38-42 mmHg
- Indicates tissue oxygenation
- Only obtained through pulmonary artery sampling
- Value <35mmHg indicates that tissue oxygenation is less than optimal
\( C_{(a-v)O_2} \)

- Arterio-venous oxygen difference
- Normal value 3.5-5vol%
- Increase = perfusion of the body organs is decreasing
- Decrease = tissue utilization of oxygen is impaired
Acid-Base Balance

- Lungs and kidneys excrete the metabolic acids produced in the body
- Breakdown of this process leads to acid-base disorders
pH

- 7.35-7.45
- Reflects the acid-base status of the arterial blood
- Majority of body functions occur optimally at 7.40, deviation from this have a profound effect on the body
\[ P_{aCO_2} \]

- 35-45 mmHg
- Reflects the respiratory component of the acid-base status
- Hypercapnia
  - hypoventilation
- Hypocapnia
  - hyperventilation
- Best parameter for monitoring the adequacy of ventilation
HCO$_3^-$

- 22-26mEq/L
- Metabolic component of the acid-base balance
- Regulated by the renal system
- Compensatory response for changes in $P_a\text{CO}_2$
Base Excess

- ± 2 mEq/L
- Reflects the non-respiratory portion of acid-base balance
- Provides a more complete analysis of the metabolic buffering capabilities

+ value: base added or acid removed
- value or base deficit: acid added or base removed
Hendersen-Hasselbalch

\[ \text{pH} = \text{pK} + \log \frac{\text{HCO}_3^-}{\text{P}_a\text{CO}_2 \times 0.03} \]

\[ \text{pK} = 6.1 \]

Defines the effects of \( \text{HCO}_3^- \) and \( \text{P}_a\text{CO}_2 \) on the acid-base balance
Acid-Base Disturbances

- Normal Acid-Base Balance
  - Kidneys maintain $\text{HCO}_3^-$ of $\sim 24$ mEq/L
  - Lungs maintain $\text{CO}_2$ of $\sim 40$ mmHg
  - Using the H-H equation produces a pH of 7.40
- Ratio of $\text{HCO}_3^-$ to dissolved $\text{CO}_2 = 20:1$
  - Increased ratio = alkalemia
  - Decreased ratio = acidemia
Clinical Recognition of Acid-Base disorders

**Respiratory Acidosis**
- Reduction in alveolar ventilation relative to the rate of carbon dioxide production
- Inadequate ventilation
- Compensated as kidneys retain HCO$_3^-$

**Respiratory Alkalosis**
- Increase in alveolar ventilation relative to the rate of carbon dioxide production
- Hyperventilation from an increased stimulus or drive to breathe
- Compensated as kidneys excrete HCO$_3^-$
Clinical Recognition of Acid-Base disorders

**Metabolic Acidosis**
- Plasma HCO$_3^-$ or base excess falls below normal; buffers are not produced in sufficient quantities or they are lost
- Respiratory response = Kussmauls respiration

**Metabolic Alkalosis**
- Elevation of the plasma HCO$_3^-$ or an abnormal amount of H+ is lost from the plasma
- Tends to remain uncompensated since patient would have to hypoventilate
Compensation for Acid-Base Disorders

- Compensation occurs within the limitations of the respiratory or renal systems.
- pH 7.38; $P_a CO_2 = 85mmHg$ with an elevated plasma $HCO_3^-$. 
Mixed Acid-Base Disorders

Respiratory and Metabolic Acidosis
- Elevated $P_aCO_2$ and reduction in $HCO_3^-$
- Synergistic reduction in pH
- Occurs in:
  - CPR
  - COPD and hypoxia
  - Poisoning, drug overdose

Respiratory and Metabolic Alkalosis
- Elevated plasma $HCO_3^-$ and a low $P_aCO_2$
- Occurs due to
  - Complication of critical care
  - Ventilator induced
Acid-Base Assessment
Oxygenation Assessment
Capillary Blood Gases

- Often used in infants and small children
- A good capillary sample can provide a rough estimate of arterial pH and PCO₂
- The capillary PO₂ is of no value in estimating arterial oxygenation
- The most common technical errors in capillary sampling are inadequate warming and squeezing of the puncture site
Blood Gas Analyzers

- Accurate measurements of pH, PCO$_2$, PO$_2$
- Electrodes
  - Sanz electrodes
  - Severinghaus electrodes
  - Clark electrodes
- Point of Care analyzers (POC)
Quality Assurance

Accurate ABG results depend on rigorous quality control efforts.

- The components of quality control are
- Record keeping (policies and procedures)
- Performance validation (testing a new instrument)
- Preventative maintenance and function checks
- Automated calibration and verification
- Internal statistical quality control
- External quality control (proficiency testing)
- Remedial action (to correct errors)