Acid-Base Disturbances
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What is it?

- **Respiratory:**
  - breathing is inadequate and carbon dioxide accumulates
  - \( \uparrow \) PCO2 contributes to an acid pH

- **Metabolic:**
  - normal metabolism is impaired - acid forms
  - if severe, the patient may be in shock
Physiology

- Carbonic acid (H2CO3) is central to our understanding and evaluation of acid-base disturbances.
- The dissociation products and the ionization products are normally in equilibrium.
Physiology: The Cell Wall

- Limits transfer of substances
- Depends on pH
  - first, as the pH changes so will the degree of ionization and, hence, the concentration of ionized substances; second, if the degree of ionization changes greatly, a substance may cease to be ionized and will, therefore, escape from the cell.
Physiology: Extracellular Fluid

- Treatable volume
- Extracellular fluid is 20% of the body weight
- Provides:
  - Nutrition
  - Oxygenation
  - Waste removal
  - Temperature
  - Alkalinity
Acid-Base Disturbances

- pH must be within small range
  - Normal is 7.4
- Large acid loads are produced by normal metabolism
Some definitions…

- pH defines the blood [H+] concentration
  - Low (<7.35) = Acidemia
  - High (>7.45) = Alkalemia
Some definitions…

- $[\text{HCO}_3]$ defines the metabolic component
  - Low ($<20 \text{ mmol/L}$) = Metabolic acidosis
  - High ($>33 \text{ mmol/L}$) = Metabolic alkalosis
More definitions…

- pCO2 defines the respiratory component
  - Low (<35 mmHg) = Respiratory alkalosis
  - High (>45 mmHg) = Respiratory acidosis
Basic Evaluation

- High pH (>7.45) suggests:
  - Respiratory alkalosis - pCO2 < 35mmHg
  - Metabolic alkalosis - [HCO3] > 33 mmol/L.
Basic Evaluation

- Low pH (<7.35) suggests:
  - Respiratory acidosis - pCO2 > 45 mmHg
  - Metabolic acidosis - [HCO3] < 23 mmol/L
Normal pH?

- Normal pH (7.35-7.45) suggests:
  - No acid-base disturbance
  - Chronic respiratory alkalosis
  - Chronic respiratory acidosis (mild)
  - Mixed disturbance
Buffer Systems

- Bicarbonate – carbonic acid system
  - Lungs excrete
- Proteins and phosphates
  - Kidneys excrete
Respiratory Acidosis

- ↓ respiratory exchange with retention of CO2 results in a ↑ pCO2 which then causes renal retention of bicarbonate
Respiratory Acidosis: Causes

- \( \downarrow \) respiratory exchange
- CNS Depression
  - trauma/infections/tumor
cerebrovascular accidents
drug overdose
- Neuromuscular disorders
  - Myopathies

- Thoracic disorders
  - hydrothorax
  - pneumothorax
- Lung disorder
  - bronchial obstruction
  - emphysema (chronic obstructive airway disease)
  - severe pulmonary edema
Respiratory Acidosis: Compensation

- Problem: ↑ pCO2 and this results in a ↓ blood pH (high H+)
- [H+] stimulates kidney to generate and retain bicarbonate
  - respiratory acidosis is compensated for by the development of a metabolic alkalosis
Respiratory Acidosis: Compensation

- Compensation is complete ([HCO3] levels out) in 2-4 days
- Final HCO3 can be calculated from the following equation:
  - \[ \text{HCO3 mmol/L} = 0.44 \times \text{pCO2 mmHg} + 7.6 \ (\pm 2) \]
- Limit of compensation is a HCO3 of 45 mmol/L
Acute: correct underlying source of alveolar hypoventilation
- Bronchodilators
- Oxygen
- Antibiotics/Drug therapy
- Dialysis

If it is chronic: try to avoid excessive supplemental oxygen
Respiratory Alkalosis

- ↑ respiratory exchange with loss of CO2 results in a ↓ pCO2 which then stimulates renal excretion of bicarbonate
Respiratory Alkalosis: Causes

- ↑ respiratory exchange
- CNS disturbances
- Psychogenic (anxiety)
- Pregnancy
- Hypoxia
- Drug toxicity / overdose

Pulmonary disorders
- Embolism
- Edema
- Asthma
- Pneumonia
Respiratory Alkalosis: Compensation

- Problem: ↓ pCO2 causing ↑ blood pH (low H+)
- ↑ pH stimulates the kidney to excrete bicarbonate
  - respiratory alkalosis is compensated for by the development of a metabolic acidosis
Respiratory Alkalosis: Compensation

- If the condition has been present for 7 days or more full compensation may occur.
- Compensation is complete ([HCO3] levels out) in 7-10 days.
- The limit of compensation is a HCO3 of 12 mmol/L.
Respiratory Alkalosis: Treatment

- Treatment aims to eradicate the underlying condition
  - removal of ingested toxins
  - treatment of fever or sepsis (toxin)
  - treatment of CNS disease

- In severe respiratory alkalosis:
  - breathing into a paper bag, which helps relieve acute anxiety and increases carbon dioxide levels
Metabolic Acidosis

↑ production or renal retention of H+ results in a low pH which stimulates respiration to ↓ the pCO2
Metabolic Acidosis: Causes

- High Anion Gap
  - Renal failure
  - Toxins
  - Ketoacidosis

- Normal anion gap (hyperchloremic)
  - Hyperkalemia
  - Obstructive uropathy
  - Diarrhea
  - Renal tubular acidosis
  - Some medications
Metabolic Acidosis: Compensation

- Problem: ↓ [HCO3] causing ↓ blood pH (high H+).
- [H+] stimulates respiration which lowers the blood pCO2
  - metabolic acidosis is compensated for by the development of a respiratory alkalosis
Metabolic Acidosis: Compensation

- Compensation is complete (pCO2 levels out) in 12-24 hours.
- The final pCO2 can be calculated from the following equation:
  \[ pCO2 \text{ mmHg} = 1.5 \times [HCO3] \text{ (mmol/L)} + 8 (+/- 2). \]
- The limit of compensation is a pCO2 of 10 mmHg
Metabolic Acidosis: Treatment

- Try to restore perfusion and correction of underlying disturbance.
- It is rarely necessary to administer sodium bicarbonate to patients with acute metabolic acidosis.
  - Not recommended for stable patients with pH 7.2 or higher.
Metabolic Alkalosis

- ↑ production or renal retention of HCO3 results in a high pH which inhibits respiration to increase the pCO2
Metabolic Alkalosis: Causes

- **↓ Urinary chloride**
  - Gut H+ loss
    - Vomiting, suction
  - Renal H+ loss
    - Diuretic therapy
    - Contraction alkalosis

- **↑ Urinary chloride**
  - Mineralocorticoid excess
  - Diuretic therapy
Metabolic Alkalosis: Compensation

- Problem: ↑ [HCO3] causing ↑ blood pH (low H+)
- Low [H+] suppresses respiration which ↑ blood pCO2
  - metabolic alkalosis is compensated for by the development of a respiratory acidosis
Metabolic Alkalosis: Compensation

- Compensation is complete (pCO2 levels out) in 12-24 hours.
- The final pCO2 can be calculated from the following equation:
  \[ \text{pCO2 mmHg} = 0.9 \times [\text{HCO}_3^-] \text{ (mmol/L)} + 9 \ (\pm 2) \]
- The limit of compensation is a pCO2 of 60 mmHg
Metabolic Alkalosis: Treatment

When metabolic alkalosis is potentially life-threatening (pH > 7.6 or [HCO3-] > 40 mEq/L):

- the carbonic anhydrase inhibitor acetazolamide should be considered; however, this agent is associated with renal loss of potassium
Metabolic Alkalosis: Treatment

- If acetazolamide is not effective or the metabolic alkalosis worsens:
  - exogenous acid, in the form of a 0.1N solution of hydrochloric acid (100 mEq/L), should be administered through a central venous catheter