Acid-Base Disturbances

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What is it?

- Respiratory:
  - breathing is inadequate and carbon dioxide accumulates
  - ↑ PCO_2 contributes to an acid pH
- Metabolic:
  - normal metabolism is impaired - acid forms
  - if severe, the patient may be in shock

Physiology

- Carbonic acid (H_2CO_3) 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…

- [HCO3] defines the metabolic component
  - Low (<20 mmol/L) = Metabolic acidosis
  - High (>33 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 - $pCO_2 < 35mmHg$
  - Metabolic alkalosis - $[HCO_3] > 33$ mmol/L.

Basic Evaluation

- Low pH (<7.35) suggests:
  - Respiratory acidosis - $pCO_2 > 45$ mmHg
  - Metabolic acidosis - $[HCO_3] < 23$ 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 CO_2 results in a ↑ pCO_2 which then causes renal retention of bicarbonate

Respiratory Acidosis: Causes

- ↓ 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: ↑ pCO_2 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:
  - HCO3 mmol/L = 0.44 X pCO2 mmHg + 7.6 (+/- 2).
- Limit of compensation is a HCO3 of 45 mmol/L

Respiratory Acidosis: Treatment

- 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 CO_2 results in a ↓ pCO_2 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: ↓ pCO_2 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 (pCO_2 levels out) in 12-24 hours.
- The final pCO_2 can be calculated from the following equation:
  - pCO_2 mmHg = 1.5 x [HCO_3] (mmol/L) + 8 (+/- 2).
- The limit of compensation is a pCO_2 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 HCO_3 results in a high pH which inhibits respiration to increase the pCO_2

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:
  - pCO2 mmHg = 0.9 X [HCO3] (mmol/L) + 9 (+/- 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