ACID-BASE BALANCE AND ACID-BASE DISORDERS

I. Concept of Balance
   - A. Determination of Acid-Base status
     1. Specimens used - what they represent

II. Electrolyte Composition of Body Fluids
   - A. Extracellular Compartment
     1. Vascular - Plasma, RBC
     2. Interstitial fluid, CSF & bone
   - B. Intracellular Compartment
   - C. Mechanism for maintaining body water levels
   - D. Mechanisms for the movement of substances between compartments
     1. Gibbs-Donnan Equilibrium
     2. Active & Passive Transport

III. Estimation of Vascular Compartment pH
   - A. Henderson-Hasselbalch Equation

$$pH = pK' + \log (c HCO_3^- / c dCO_2)$$

Average ratio of log term is about 20/1

pH imbalances of metabolic origin are classified as primary disturbances of $[HCO_3^-]$, while those of respiratory origin are considered primary disturbances of $[dCO_2]$

IV. Acid-Base Parameters - Definitions and Abbreviations

Bicarbonate - plasma bicarbonate, carbonate and CO_2 bound in plasma carbamino compounds

Dissolved CO_2 (dCO_2) - free CO_2 + H_2CO_3

Partial Pressure of CO_2 (pCO_2) - $\alpha pCO_2 = [dCO_2]$

Total CO_2 (tCO_2) = $[HCO_3^-]$ + $[dCO_2]$
Standard $[HCO_3^-]$ of blood
Base Excess of the Extracellular fluid or Standard
Base Excess: Concentration of titratable base when titrating a model of extracellular fluid to a pH of 7.4 at a pCO_2 of 40 mm Hg.
pH: - log aH^+. $[H^+] = K(pCO_2/cHCO_3^-)$

V. Buffer Systems and Their Role in Regulating the pH of Body Fluids

A. Bicarbonate/Carbonic Acid Buffer System

$$\beta HCO_3^- = (\Delta[HCO_3^-]/\Delta pH)$$

$$\beta HCO_3^-, \text{closed} = 2.303\,[tHCO_3^-]\{K'aH^+/(K' + aH)^2\}$$
$$= 2.7 \text{ mM}$$

$$\beta HCO_3^-, \text{open} = 2.303[HCO_3^-] = 56.6 \text{ mM}$$

B. Phosphate Buffer System
C. Plasma Protein Buffer System: imidazole side chains
D. Hemoglobin Buffer System

VI. Isohydric & Chloride Shift

VII. Respiratory Mechanism in the Regulation of Acid-Base Balance

VIII. Renal Excretion of Acid, Ammonia Formation and Reabsorption of Bicarbonate - Renal Compensatory Mechanism

A. Excretion of Acids
B. Na^+-H^+ Exchange
C. Renal Production of Ammonia & Excretion of NH_4^+
D. Excretion of H^+ as $H_2PO_4^-$
E. Reclamation of Filtered Bicarbonate

ACID BASE BALANCE AND ACID BASE DISORDERS - II

1. Conditions Associated with Abnormal Acid-Base Status and Abnormal Anion-Cation Composition of the Blood

- Assumes that extracellular composition is same as intracellular composition
- Anion & cation shifts accompany alterations in H^+
  Anion to balance H^+, cation to balance organic acid anions
- Separated into respiratory (acidosis and alkalosis) and metabolic (acidosis and alkalosis)
- Compensatory mechanisms may fully, partially or <u>not</u> restore acid-base balance

A. Metabolic Acidosis

1. Production of organic acids > excretion of these acids
2. Decreased urinary excretion of acids
3. Excessive loss of HCO_3^- due to loss of duodenal fluid

$$pH = pK' + \log([HCO_3^-]/[dCO_2]$$

Symptoms: hyperventilation, acidic urine

4. Normal Anion Gap Acidoses
   a. Hypokalemic
      1. Diarrhea
      2. Renal tubular acidosis
      3. Carbonic anyhydrase inhibitors
      4. Ureterosigmoidostomy

b. Normokalemic
    1. Early renal failure
    2. Hydronephrosis
    3. Treatment with NH_4^+, Arg-HCl
    4. Hypoaldosteronism or aldosterone-antagonizing drugs

c. Hyperkalemic
    1. Severe inhibition of renal NH_4^+ formation
    2. Severe reaction to aldosterone antagonists, renin synthesis failure, advanced Addison's disease, renal resistance to aldosterone

5. Increased Anion Gap Acidosis
    a. Renal Failure
    b. Ketoacidosis
    c. Salicylate intoxication
    d. Lactic Acidosis
        Type A - severe hypoxia
        Type B - drugs & toxins, defects in gluconeogenesis enzymes, severe acidoses

    Lactate + NAD^+ <=====> Pyruvate + NADH + H^+

6. Compensatory Mechanisms
    a. Respiratory (decreased dCO_2)
    b. Renal

7. Lab Findings:

    $[HCO_3^-] + 15 = 25$ pH = 7.**25**
    $pCO_2 \pm 2 = 1.5[HCO_3^-] + 8$

Diabetic Ketoacidosis

B. Metabolic Alkalosis

1. Administration of excess alkali
2. Excessive loss of HCl from stomach
3. K^+ depletion
4. Renal bicarbonate retention
5. Prolonged administration of thiazide diuretics

Symptoms - hypoventilation

6. Compensatory Mechanisms - hypoventilation
7. Lab Findings. Use formulas

C. Respiratory Acidosis

1. Respiratory Center Depression
2. Obstruction - both blockage & scarring of alveoli
3. Abdominal Distention, extreme obesity, extreme scoliosis, sleep apnea
4. Compensatory Mechanisms
   a. Increased depth & volume of breathing
   b. Renal
5. Lab Findings: pH > 7.20, usually uncomplicated

$$\triangle cH^+ = 0.8(\triangle pCO_2)$$

D. Respiratory Alkalosis

1. Nonpulmonary Stimulation of Respiratory Center
2. Pulmonary Stimulation of Respiratory Center
3. Ventilation-Induced

4. Compensatory
    a. Renal
5. Lab Findings

E. Anion Gap

F. Osmolal Gap Calculation - useful at identifying presence of osmotically active unknown substance

Osmolal Gap = Observed - Calculated

Calculated: $1.86[Na^+] + [Glu] + [Urea] + 9$

G. Use of acid-base nomograms