Chapter 3
Disorder of Water, Electrolyte and Acid-base
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Disorder of Water and Electrolyte

1. Dehydration
   • It is a disturbance of water or electrolytes or both
   • It is disturbance of water balance in which the output exceeds the intakes, causing a reduction of body water below the normal level

2. Water Intoxication
   • It is caused by excess of water retention in the body
Types of Dehydration

1. Primary Depletion (Pure water depletion)
2. Secondary Depletion (Pure salts depletion, Sodium depletion)
3. Mixed Depletion; in which both occur

Primary Depletion

• Definition
  • It occurs when intake is stopped or water intake is inadequate and there is no parallel loss of salt in the secretions from the body
Primary Depletion, Cont’d

• Causes
  1. When person is too weak or too ill to satisfy his/her water needs
  2. In mental person who refuses to drink
  3. In cases of coma, dysphagia (difficultly in swallowing)
  4. In individual lost in desert or shipwrecked

Pathophysiology

1. Water depletion occurs almost always because of lack of intake, rather than because of losses from the body

2. When a person stops his intake of water, body water stores become depleted, because of continuing “obligatory losses” and later on, supplemented by the continued excretion of “minimal volume” of urine required for excretion of “metabolic loads”
3. Only source of water supply for the body in the complete absence of intake of water becomes the water obtained from oxidation of food staffs (metabolic water)

4. As obligatory water loss continues, the concentration of the electrolytes rises in the ECF, which becomes “hypertonic” (hyperosmolar)

5. Water moves from ICF to ECF to correct this imbalance and to maintain uniform osmotic pressure throughout the body

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5. Thus the volume of ECF is maintained almost to normal at the expense of ICF which is grossly reduced in volume causing intracellular dehydration
A = Plasma; B = Tissue Fluid; A + B = Extracellular Fluid (ECF); C = Intracellular Fluid (ICF)

1. Cellular dehydration
2. ECF volume is almost maintained

Figure Showing distribution of body water in three compartments in primary dehydration

Clinical and Biochemical Significance

1. Thirst is the earliest symptom due to intracellular dehydration
2. Dehydration is shown by a dry tongue and pinched fancies
3. Oliguria: hyperosmolarity stimulates the releases of ADH which causes reassertion of water from the kidney tubules, causing a gradual diminution of urine volume
Clinical and Biochemical Significance, Cont’d

4. A normal or slightly increased blood urea, reduced plasma volume may occur
5. There is usually no circulatory collapse or fall in blood pressure as the plasma volume is maintained
6. Urinary chloride will contain NaCl rather than it is to higher side

Death

• Occurs when has loss amounts to approximately 15% of body weight (about % of total body water) which happens on about the 7th to 10th day of complete water deprivation and if NOT treated
Secondary Depletion

• Definition
  • It occurs when fluids of high sodium or chloride content are lost from the body and are replaced by salt-deficient fluids such as water by mouth or glucose solution IV
  • It is called now sodium depletion rather than salt depletion to lay stress on the fact that Na is the significant ion concerted with the maintenance of ECF volume

Causes

1. Loss of Na can occur by excessive sweating when only water is taken in as replacement
2. Loss of gastrointestinal fluids as in vomiting, diarrhea or biliary fistulæ's, cholera and continue aspirations through intubations
Causes, Cont’d

3. Urinary loses of Na are NOT as common as Addison’s syndrome, but can occur as in diabetic acidosis, cerebral salt-washing syndrome and certain instances of chronic renal diseases
4. Vigorous uses of diuretics and low Na or salt-free diets in the management of congestive heart failure may induce Na depletion

Pathophysiology

1. ECF becomes hypotonic
2. The lowered osmotic pressure inhibits the release of ADH and the kidneys excrete water in an attempt to maintain normal EC Na levels
3. Because of the above, plasma and interstitial fluid volume are decreased

4. Extracellular hypotonic allows water to flow into the cells where the level is greater, thus further reducing the volume of ECF and it leads to the cellular hydration in contrast to cellular dehydration noted in primary depletion

Figure  Showing distribution of body water in three compartments in secondary dehydration
Clinical and Biochemical Significance

1. Because of hypotonicity, thirst is NOT a striking feature and absence of thirst is an important negative finding
2. Person appears apathetic and listless, mental changes are common and hallucinations and confusion are common and sometimes delirious
3. Anorexia and nausea and vomiting often aggravates the vicious circle of Na depletion:

Vicious Circle of Na Depletion

- Anorexia
- Loss of NaCl
- Salt depletion
- Na Depletion

Anorexia
Clinical and Biochemical Significance, Cont’d

4. Cramps are common and may occur in high, duodecimal and respiratory muscles

5. Loss of interstitial fluid is manifested clinically by sunken eyes and inelastic skin

6. Reduced plasma volume leads to hemococoncentration. As a result of lowered blood volume there are decreased cardiac output, lowering of blood pressure and a tendency to orthostatic fainting

7. Decreased glomerular filtration leads to nitrogen retention with increase urea concentration

8. Urinary analysis: person drinking freely maintain a normal or slightly increased urinary volume, but there is no salt present in the urine (except in Addison’s disease)
   - **Death**
     - Due to oligemic shock
Mixed Water and Sodium Depletion

- **Definition**
  - It is more common than depletion of either alone
  - It occurs when there is loss of fluids containing high concentration of Na and Cl without of a free intake of water

- **Pathophysiology**
  - Initially the ECF is hypotonic. Later water loss outstrips the salt loss and ECF becomes hypertonic

Clinical and Biochemical Significance

1. The clinical picture is a mixture of primary and secondary depletion
2. The volume of fluid in both ECF and ICF is reduced
3. The person appears dehydrated and complains of thirst
Clinical and Biochemical Significance, Cont’d

4. The blood pressure may be lowered, blood urea and hemo concentration are raised
5. Urinary output is diminished and excretion of salt is reduced

Types of Fluids to Administer

• For Primary Dehydration
  • Water by mouth or per rectum or 5% glucose by IV, SC or IP routes depending on the cases
  • Note: never give isotonic saline which increase hypertonicity
Types of Fluids to Administer, Cont’d

• For Secondary Dehydration
  • Isotonic saline solution

• For Mixed Type Dehydration
  • A mixture of saline and 5% glucose solution usually:
    • 1: 1 (0.5 normal saline solution)
    • 1: 2 (0.33 normal saline solution)

Regulation of Dehydration and Rehydration
Action of ADH

Regulation of Water Intake: Thirst Mechanism
Mechanisms and Consequences of ADH Release

Water Intoxication

- **Definition**
  - It is caused by excess of water retention in the body

- **Causes**
  1. Renal failure
  2. Excessive of administration of fluids
  3. Hyper secretion of ADH following administration of an anesthetic for surgery
  4. Excess of aldosterone
Clinical and Biochemical Significance

1. Headache, nausea, in coordination of movements, muscular weakness and delirium
2. PCV, Hb concentration, and plasma proteins concentrations are reduced
3. Plasma electrolytes are lowered
4. Urinary volume is usually increased and its specific gravity is low

• Treatment
  • Withholding fluids by mouth and administering 3-5% hypertonic saline IV

Acid-base Disorders

• Basic Terminology
  1. Acidemia is present when blood pH < 7.35
  2. Alkalemia is present when blood pH > 7.45
  3. Acidosis is a process that will result in acidemia if left unopposed
  4. Alkalosis is a process that will result in alkalemia if left unopposed
  5. Metabolic refers to a disorder that results from a primary alteration in [H+] or [HCO₃⁻]
  6. Respiratory refers to a disorder that results from a primary alteration in PCO₂ due to altered CO₂ elimination
Acid-base Disorders

1. Simple (Primary) Acid-base Disorder: have one primary abnormality
   - Respiratory acidosis
   - Respiratory alkalosis
   - Metabolic acidosis
   - Metabolic alkalosis

2. Mixed Acid-base Disorder: have more than one primary abnormality
   - Two to three primary disorders can be combined together to result in a mixed disorder

Acid-base Disorder, Cont’d

[Diagram showing the process of analyzing arterial blood samples to determine acid-base status, with branches for acidosis, alkalosis, and mixed disorders based on pH, bicarbonate, and oxygen partial pressure.]
Acidosis

- pH of body fluids below 7.35
  1. Respiratory acidosis
     - Caused by inadequate ventilation
  2. Metabolic acidosis
     - Results from all conditions other than respiratory that decrease pH

Alkalosis

- pH of body fluids above 7.45
  1. Respiratory alkalosis
     - Caused by hyperventilation
  2. Metabolic alkalosis
     - Results from all conditions other than respiratory that increase pH
Respiratory Ventilation

1. Normal, Unassisted Breathing
   • An increase in arterial $P_{CO_2}$ acts through the respiratory center to increase the rate of pulmonary ventilation
   • A decrease in arterial $P_{CO_2}$ reduces the rate of ventilation

2. Assisted Breathing
   • A respirator is used to assist breathing by expelling $CO_2$, thus reducing $PCO_2$ in blood

Respiratory Acidosis

[Diagram showing the cause of acidosis, compensation by renal buffering, and the effect on pH]

[Chemical reactions and pH changes shown in the diagram]
Respiratory Acidosis Causes

1. Damage of CNS
2. Respiratory problem
   - Hypoventilation
   - Asthma
   - Pneumonia

Respiratory Acidosis Causes, Cont’d

3. Pain
   - Chest
   - Tightness
   - Cough
   - Wheeze
Respiratory Alkalosis

1. Stimulation of respiratory center
   - CNS diseases
   - Salicylate poisoning
   - Hyperpyrexia
   - Fevercoma
Respiratory Alkalosis Causes, Cont’d

2. Hysteria
3. Apprehensive blood donor
4. High altitude ascending
5. Hepatic

Metabolic Acidosis
Metabolic Acidosis, Cont’d

- Acidosis will cause more potassium ions to be moved extracellularly in exchange for hydrogen ions
- Hyperkalemia may result

Metabolic Acidosis Causes

1. Diabetic acidosis
2. Lactic acidosis
3. Starvation
4. High fever
5. Violent exercise
Metabolic Acidosis Causes, Cont’d

6. Hemorrhage
7. Anoxia
8. Renal failure
9. Heart failure
10. Diarrhoea
Metabolic Alkalosis, Cont’d

- Alkalosis will cause more hydrogen ions to be moved extracellularly in exchange for potassium ions
- Hypokalemia may result

Metabolic Alkalosis Causes

1. Vomiting
2. Alkali administration
3. Potassium deficiency
4. Radiation therapy
### Acid-base Changes in Acidosis and Alkalosis

<table>
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<th>pH</th>
<th>HCO$_3^-$</th>
<th>PCO$_2$</th>
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Thicker arrows indicate primary disorder

### Acid-base Changes in Acidosis and Alkalosis, Cont’d

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pH, PCO$_2$ in opposite directions; HCO$_3^-$ will follow PCO$_2$.

pH, HCO$_3^-$ in same direction; PCO$_2$ will follow HCO$_3^-$.

Thicker arrows indicate primary disorder
Acidosis and Alkalosis

Table A Acidosis and Alkalosis

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<td><strong>Respiratory Acidosis</strong>&lt;br&gt;Reduced elimination of CO$_2$ from the body fluids</td>
<td><strong>Respiratory Alkalosis</strong>&lt;br&gt;Reduced CO$_2$ levels in the extracellular fluid (e.g., hyperventilation due to emotions)</td>
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<td>Asphyxia</td>
<td>Decreased atmospheric pressure reduces oxygen levels, which stimulates the chemoreceptor reflex, causing hyperventilation (e.g., high altitudes)</td>
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<td>Hypoventilation (e.g., impaired respiratory center function due to trauma, tumor, shock, or renal failure)</td>
<td><strong>Metabolic Alkalosis</strong>&lt;br&gt;Elimination of H$^-$ and reabsorption of HCO$_3^-$ in the stomach or kidney (e.g., severe vomiting or formation of acidic urine in response to excess aldoxidase)</td>
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<td>Advanced asthma</td>
<td>Ingestion of alkaline substances (e.g., large amounts of sodium bicarbonate)</td>
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<td>Severe emphysema</td>
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Elimination of large amounts of HCO$_3^-$ resulting from excessive secretion (e.g., severe diarrhea and vomiting of lower intestinal contents)
Direct reduction of the body fluid pH as acid is absorbed (e.g., ingestion of acidic drugs like aspirin)
Production of large amounts of fatty acids and other acidic metabolites, such as ketone bodies (e.g., untreated diabetes mellitus)
Inadequate oxygen delivery to tissue resulting in anaerobic respiration and lactic acid buildup (e.g., exercise, heart failure, or shock)

Any questions?