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Water content in humans

(a) Distribution of body water in an average lean, adult female and male
(b) Exchange of water among body fluid compartments
Age and water content

- Normally body fluid volume remains constant
  - **water loss = water gain**
- Water gain:
  - ~60% ingested liquids
  - ~30% ingested foods
  - ~10% metabolic water (from oxidation)
- Water loss:
  - ~4% faeces
  - ~28% insensible water loss (skin & lungs)
  - ~8% perspiration
  - ~60% urine

Water balance
Electrolites in body fluid compartments

<table>
<thead>
<tr>
<th>INTRACELLULAR</th>
<th>EXTRACELLULAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>POTASSIUM (K⁺)</td>
<td>SODIUM (Na⁺)</td>
</tr>
<tr>
<td>MAGNESIUM (Mg²⁺)</td>
<td>CHLORIDE (Cl⁻)</td>
</tr>
<tr>
<td>PHOSPHOROUS (P)</td>
<td>BICARBONATE (HCO₃⁻)</td>
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ECF is ~ 20% of body weight

- **Sodium** (Na⁺) determines the volume of water that is outside the cells (blood, interstitial fluid, and in body cavities).
- **Na⁺ retention** causes this volume to expand
- **Na⁺ loss** of sodium causes this volume to decrease

- Water moves freely within intracellular and extracellular compartments, keeping osmolality equal
Transmembrane transports

The maintenance of normal volume and normal composition of the extracellular fluid is vital to life.

Three types of homeostasis are involved in this maintenance: fluid balance, electrolyte balance, and acid-base balance.

Exchange occurs between the ICF and ECF.
Systems engaged in the regulation

- Renal System
- Cardiovascular System
- Nervous System
- Endocrine
- Respiratory System
- GI System
- Integumentary System (skin, mucous membranes)

Regulation of ECF Volume

Kidneys
- The kidneys respond to reduced blood flow by releasing the enzyme renin.
- Renin initiates the activation of the protein angiotensinogen to angiotensin.
- Adrenal glands secrete aldosterone.
- Blood vessels constrict, raising pressure.
- Kidneys retain sodium and water, thus increasing blood volume.

Brain
- The hypothalamus responds to high salt concentrations in the blood by stimulating the pituitary gland.
- The pituitary gland releases antidiuretic hormone (ADH).

Blood
- Blood vessels
- Renin
- Angiotensin
- Aldosterone
- ADH
Regulation of ECF Volume

Increased blood pressure in right atrium

Increased ANH

Increased Na+ excretion and increased water loss result in decreased BP

Tonicity of ECF

Refers to osmolality of a solution

- **Isotonic**: same osmolality of body fluids (0.9% NaCl) (240-349 mOsm)
- **Hypertonic**: higher osmolality than body fluids. (3% NaCl)
- **Hypotonic**: lower osmolality than body fluids. (0.45% NaCl)
**Tonicity of ECF**

- **Dehydration** – extracellular fluid volume deficit resulting either from inadequate intake or excessive loss or both

- **Hypovolemia** – “isotonic dehydration” - Water and electrolyte losses are equal; vascular fluid volume deficit

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**Fluid Volume Deficit**

- **Dehydration** - extracellular fluid volume deficit resulting either from inadequate intake or excessive loss or both

- **Hypovolemia** – “isotonic dehydration” - Water and electrolyte losses are equal; vascular fluid volume deficit
Dehydration Types

- Isotonic
- Hypotonic
- Hypertonic

Mild = 2% of body weight loss
Moderate = 5% of body weight loss
Severe = 8% or more of body weight loss

Causes of Dehydration

- Lack of intake
  - Dysphagia / risk of aspiration
  - Tube fed individuals
  - Impaired thirst mechanism
- Excessive fluid losses
  - Vomiting
  - Diarrhea
  - Fever
  - GI suction
  - Blood loss
  - Burns
Signs and symptoms of dehydration

- Thirst
- Weight loss
- Decreased urine output
- Urine specific gravity increases (over 1.030)
- High hematocrit
- Increased heart rate (HR)
- Decreased blood pressure (BP)
- Low skin turgor
- Fever with dehydration, subnormal temp with hypovolemia, lassitude

Fluid Volume Overload

- Hypervolemia
- Causes:
  - Excess intake of fluids
  - Excess intake of sodium
  - Compromised regulatory mechanisms
    - CHF
    - Cirrhosis
    - Renal failure
    - SIADH
  - Normal post-operative response
Pathophysiology of Fluid Volume Overload

- Normal compensatory mechanisms kick in
- If not treated –
  - Increased pressure at the arterial end of capillary bed causes movement of fluid into interstitial spaces
  - Increased pressure in left ventricle then left atrium
  - Then back-up into lungs leading to pulmonary edema
  - Can lead to CHF

Clinical Manifestations

- Weight gain
- Dyspnea
- Cough
- Crackles
- Pleural effusion
- Jugular vein distention
- Edema
- Increased BP
Clinical assessment of patient with fluid and electrolyte disorder

- Health History
- Daily Weight
- Fluid Intake and Output
- Vital Signs
- Skin Turgor
- Mucous Membranes
- Hand Vein Filling/Emptying
- Labs – Urine SG; Na⁺; Total Protein; Albumin; Serum Osmolarity; BUN; Creatinine

Edema

- Definition
  - Edema = Accumulation of water in interstitial space
  - Collections of fluid in body cavities
    - Hydrothorax
    - Hydroperitoneum (ascites)
    - Hydropericardium
  - Anasarca = severe, generalized edema with profound subcutaneous edema
Types of Edema

- Localized
  - Inflammation
  - Lymphatic Obstruction
  - Venous Obstruction
  - Thrombophlebitis

- Generalized
  - Cardiac
  - Hepatic
  - Renal
    - Nephrotic Syndrome
    - Acute GN
    - Idiopathic
  - Other
    - Cyclic
    - Myxedema
    - Vasodilator-induced
    - Pregnancy-induced
    - Capillary leak syndrome

Pathophysiology of Edema

- The normal flow of fluid through the interstitial space depends on four factors:
  - Capillary hydrostatic pressure that filters fluid from the blood through the capillary wall
  - Oncotic pressure exerted by the proteins in the blood plasma
  - Permeability of the capillaries
  - Presence of open lymphatic channels that collect some fluid forced out of the capillaries by the hydrostatic pressure of the blood and return the fluid to the circulation
Mechanisms of edema formation

Summary

- Increased hydrostatic pressure
- Reduced plasma oncotic pressure
- Decreased lymph outflow (lymphatic channel obstruction)
- Increased capillary membrane permeability
- Retention of water and salts

Hydrostatic pressure increases due to:

- **Venous obstruction:**
  - thrombophlebitis (inflammation of veins)
  - hepatic obstruction
  - tight clothing on extremities
  - prolonged standing
- **Salt or water retention**
  - congestive heart failure
  - renal failure
Increased Hydrostatic Pressure

- ↓ plasma albumin
  - liver disease
  - protein malnutrition
- plasma proteins lost in:
  - glomerular diseases of kidney
  - hemorrhage, burns, open wounds

Decreased plasma oncotic pressure:
Hypoproteinemic edemas

- Ascites
- Nephrotic syndrome

Increased capillary permeability

- Inflammation
- Immune responses
- Toxines
**Inflammatory edema**

- Surgery
  - Breast carcinoma with lymph node removal
- Blocked lymphatics
  - Hematologic conditions
  - Parasitoses

**Lymphatic channels blocked**
Lymphatic obstruction

Elephantiasis

Breast carcinoma surgery with lymphatic dissection

Caused by thread-like parasitic worm – filaria (filariasis) transmitted by mosquitoes

Effects of Edema

- Swelling
- Pitting
- Increased body weight
- Functional impairment
- Pain
- Impairment of arteriole circulation
- Other complications (as always!)
Clincal Consequences of Edema

- In skin edema may cause poor wound healing or poor clearance of infection
- Edema in a closed space such as the calvarium can cause increased pressure, which may cause herniation of the brain

Acute pulmonary edema

Definition:
An increase in pulmonary extravascular water, which occurs when transudation or exudation exceeds the capacity of lymphatic drainage.
Stages of pulmonary edema

1. Interstitial pulmonary oedema
2. Crescentic alveolar filling
3. Alveolar flooding
4. Airway flooding

- With gradual onset these may be identifiable clinically, however with fulminant disease progression may be obscured
- There is usually prodromal stage in which lymphatic drainage is increase, though there is no detectable increase in lung water

Cardioigenic pulmonary edema

- Increased hydrostatic pressure secondary to elevated pulmonary venous pressure
- Interstitial edema
- Alveolar edema
Toxic pulmonary edema

Increased vascular permeability due to toxic damage of pulmonary capillaries.

High Altitude Pulmonary Edema (HAPE)

- Hypoxic vasoconstriction
- Blood vessel leakage
- Fluid builds up in the lungs
Thank you