Body Fluids

Ref: Textbook of Medical Physiology
Pages: 285-297
Fluid Compartments

(a) Distribution of body solids and fluids in an average lean, adult female and male

(b) Exchange of water among body fluid compartments
Fluid Compartments

• Of the 40 liters of water in the body of an average adult, about two-thirds is intracellular fluid and one-third is extracellular fluid.
• An average adult female is about 52% water by weight, and an average male about 63% water by weight.
Water Distribution

Total body water

- Intracellular fluid (63%)
- Extracellular fluid (37%)
- Membranes of body cells
- Interstitial fluid
- Plasma
- Lymph
- Transcellular fluid
Water Distribution

Transcellular Fluids

- Synovial
- Pericardial
- Pleural
- Peritoneal
- Ocular
- Cerebrospinal
Movement of Fluids between Compartments

Major factors that regulate movements:
- Osmotic pressure
- Hydrostatic pressure
Composition of Body Fluids

Key:
- Blood plasma
- Interstitial fluid
- Intracellular fluid

<table>
<thead>
<tr>
<th></th>
<th>Blood plasma</th>
<th>Interstitial fluid</th>
<th>Extracellular fluids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>142 mEq/liter</td>
<td>145 mEq/liter</td>
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<tr>
<td>K⁺</td>
<td>4 mEq/liter</td>
<td>4 mEq/liter</td>
<td></td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>3 mEq/liter</td>
<td>0.2 mEq/liter</td>
<td></td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>2 mEq/liter</td>
<td>2 mEq/liter</td>
<td></td>
</tr>
<tr>
<td>Cl⁻</td>
<td>100 mEq/liter</td>
<td>100 mEq/liter</td>
<td></td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>24 mEq/liter</td>
<td>27 mEq/liter</td>
<td></td>
</tr>
<tr>
<td>HPO₄²⁻ (organic)</td>
<td>15 mEq/liter</td>
<td>15 mEq/liter</td>
<td></td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>20 mEq/liter</td>
<td>20 mEq/liter</td>
<td></td>
</tr>
<tr>
<td>Protein anions</td>
<td>2 mEq/liter</td>
<td>2 mEq/liter</td>
<td></td>
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</tbody>
</table>

27.06
The volume of water gained each day varies among individuals averaging about 2,500 milliliters daily for an adult:

- 60% from drinking
- 30% from moist foods
- 10% as a by-product of oxidative metabolism of nutrients called water of metabolism
Water Balance

WATER GAIN

- Metabolic water (200mL)
- Ingested foods (700 mL)
- Ingested liquids (1600 mL)

WATER LOSS

- GI tract (100mL)
- Lungs (300 mL)
- Skin (600 mL)
- Kidneys (1500 mL)
Water normally enters the body only through the mouth, but it can be lost by a variety of routes including:

- Urine (60% loss)
- Feces (6% loss)
- Sweat (sensible perspiration) (6% loss)
- Evaporation from the skin (insensible perspiration)
- The lungs during breathing

(Evaporation from the skin and the lungs is a 28% loss)
Water Balance

**WATER GAIN**
- Metabolic water (200 mL)
- Ingested foods (700 mL)
- Ingested liquids (1600 mL)

**WATER LOSS**
- GI tract (100 mL)
- Lungs (300 mL)
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- Kidneys (1500 mL)
Water and Electrolytes Homeostasis

Systems involved in the regulation of fluids and electrolytes

- Kidneys,
- Cardiovascular system,
- Endocrine (Pituitary, Parathyroids, Adrenal glands)
- Lungs
Movement of Fluids between Compartments

Major factors that regulate movements:
- Osmotic pressure
- Hydrostatic pressure
Regulation of Na+ and Water

Involves regulation of:

- Osmolality
- Volume of ECF
different regulations with many overlapping mechanisms.
Importance of Na+ and Water regulation
(a) **Consequences of dehydration.** If more water than solutes is lost, cells shrink.

(b) **Consequences of hypotonic hydration (water gain).** If more water than solutes is gained, cells swell.
Excessive blood loss, sweating, vomiting, or diarrhea coupled with intake of plain water

Decreased Na⁺ concentration of interstitial fluid and plasma (hyponatremia)

Decreased osmolarity of interstitial fluid and plasma

Osmosis of water from interstitial fluid into intracellular fluid

Water intoxication (cells swell)

Convulsions, coma, and possible death
Measurements of Body Fluids
Measuring Body Fluids

Dilution Principle
Dilution method for calculating fluid volume

If 1 ml of a 10 mg/ml solution is injected into a fluid compartment, and the final concentration is 0.01 mg/ml, the volume of the fluid compartment is:

$$\text{Volume B} = \frac{1 \text{ ml} \times 10 \text{ mg/ml}}{0.01 \text{ mg/ml}} = 1000 \text{ ml}$$
Properties of tracers used for calculation of volumes

- Properties of an Ideal Tracer The tracer should:
  - be nontoxic
  - be rapidly and evenly distribute throughout the nominated compartment not enter any other compartment.
  - not be metabolized.
  - not be excreted (or excretion is able to be corrected for) during the equilibration period.
  - be easy to measure
  - not interfere with body fluid distribution
Measurement of Total Body Water

* Radioactive water ($^3\text{H}_2\text{O}$, Tritium) or heavy water ($^2\text{H}_2\text{O}$, Deuterium).

This will mix with the total body water in just a few hours and the dilution method for calculation can be used.

* Antipyrine
Measurement of ECF volumes

- $^{22}\text{Na}^+$, (Sodium Space)
- $^{125}\text{I}$-iothalamate,
- Thiosulfamate,
- Inulin (Inulin Space)

(Measured in 30-60 minutes)
Calculation of ICF (Intra-Cellular Volume)

ICF = Total Body water - ECF
Measurement of Plasma volumes

Measurement of Total Blood Volume
(a) Appearance of centrifuged blood

(b) Components of blood

Whole blood 8%
- Plasma (55%)
- Other fluids and tissues (92%)

Blood plasma 55%
- Proteins 7%
- Water 91.5%
- Other solutes 1.5%

PLASMA (weight)
- Albumins 54%
- Globulins 38%
- Fibrinogen 7%
- All others 1%

SOLUTES
- Electrolytes
- Nutrients
- Gases
- Regulatory substances
- Waste products

BODY WEIGHT
- Formed elements 45%
- Platelets 150,000–400,000
- White blood cells 5,000–10,000

VOLUME
- Red blood cells 4.8–5.4 million

FORMED ELEMENTS (number per μL)
- Neutrophils 60–70%
- Lymphocytes 20–25%
- Monocytes 3–8%
- Eosinophils 2–4%
- Basophils 0.5–1.0%

WHITE BLOOD CELLS
Plasma Composition

- **Water**: > 90%
- **Small molecule**: 2%, it is electrolytes, nutriment, metabolic products, hormone, enzymes, etc.
- **Protein**: 60-80 g/L, plasma protein include albumin (40-50 g/L)(54%), globulins (20-30 g/L, α₁-, α₂, β-, γ-) (38%) and fibrinogen (7%). Most of albumin and globulin made from liver.
<table>
<thead>
<tr>
<th>Measurement of Plasma volumes</th>
<th>Measurement of Total Blood Volume</th>
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<tbody>
<tr>
<td>* $^{125}$I-Albumin (RISA),</td>
<td>* $^{51}$Cr-labeled Red Blood Cells</td>
</tr>
<tr>
<td>* Evans Blue (Dye (T1824))</td>
<td>* <strong>Calculated</strong> As = Plasma Volume 1-Hematocrit</td>
</tr>
</tbody>
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