Chapter 4

**Fluid and Electrolyte Balance**

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TOTAL BODY WEIGHT

- 40% SOLIDS
- 60% FLUIDS

  - 2/3RD ICF
  - 1/3RD ECF

  - 80% INTERSTITIAL FLUID
  - 20% PLASMA
COMPOSITION OF BODY FLUIDS

SOLUTES:

ELECTROLYTES – Inorganic salts, acids, bases, and proteins

NON ELECTROLYTES – Glucose, urea, creatinine

FUNCTIONS:

Secretory activity
Neuro muscular excitability
Controlling fluid movements
## CHIEF ELECTROLYTES IN BODY FLUID COMPARTMENTS

<table>
<thead>
<tr>
<th>INTRACELLULAR</th>
<th>EXTRACELLULAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>POTASSIUM</td>
<td>SODIUM</td>
</tr>
<tr>
<td>PHOSPHATE</td>
<td>CHLORIDE</td>
</tr>
<tr>
<td>MAGNESIUM</td>
<td>BICARBONATE</td>
</tr>
</tbody>
</table>
OSMOSIS

Osmosis is the net movement of water molecules across a Partially-permeable membrane DUE TO CONCENTRATION DIFFERENCE OF SOLUTES.
TO EXPRESS CONCENTRATION OF PARTICLES IN SOLUTION - OSMOLE

1 OSMOLE = 1 GRAM MOLECULAR WEIGHT OF OSMOTICALLY ACTIVE PARTICLES.

**EX: 180 Gms OF GLUCOSE = 1 OSMOLE.**

58.5 Gms OF NaCl = 2 OSMOLE.
**OSMOLALITY**

**Definition:** Concentration of particles (osmotically active) in solution. It is usually expressed in millosmoles of solute per kg of solution.

Osmolality is independent of valency.

Osmolarity is expressed in milliosmoles of solute per litre of solution.

Plasma: 280-300 mOsm/Kg

Same in all body compartments

Water distribution
TONICITY

A property of a solution that depends on the osmotic force exerted across the membrane as influenced by the differing concentrations of solutes in and out of the cell.

Isotonic
Hypertonic
Hypotonic
Solution is Isotonic

Water goes in both directions
Solution is Hypertonic

Water moves out of the cell

Water Molecules

20% Salt

10% Salt
Solution is Hypotonic

Water moves into the cell

Water Molecules

10% Salt

20% Salt
Osmotic pressure 28 mmHg

Arteriolar end

Venous end

Hydrostatic pressure (BP) 35 mm Hg

Hydrostatic pressure (BP) 15 mm Hg

Net inward pressure 6.7 mmHg

Net outward pressure 13.3 mmHg

FORCES THAT MAINTAIN FLUID BALANCE

Hydrostatic pressure

Osmotic pressure

Net outward pressure

Hydrostatic pressure

Osmotic pressure

Net inward pressure 6.7 mmHg
Average daily intake of water

- Water of metabolism (250 mL or 10%)
- Water in food (500 mL or 20%)
- Water in beverages (1,500 mL or 60%)

Total intake (2,500 mL)

Average daily output of water

- Water lost in sweat (150 mL or 6%)
- Water lost in feces (150 mL or 6%)
- Water lost through skin and lungs (1,200 mL or 28%)
- Water lost in urine (1,500 mL or 60%)

Total output (2,000 mL)

Total intake (2500ml)
REGULATION OF BODY WATER

- Water loss
- Increased plasma osmolality
  - Stimulation of vasopressin release
    - Renal water retention
  - Stimulation of hypothalamic centre
    - Increased water intake
    - Restoration of ECF osmolality
  - Redistribution of water from ICF
    - Increased ECF water
**Fluid Disturbances**

- **Isotonic contraction**
  - Loss of GI fluid-SI fistula, SI obstn (fluid accumulates in lumen)

- **Hypotonic contraction**
  - Addison's (aldosterone def), infusion of fluids with low Na eg. dextrose

- **Hypertonic contraction**
  - Diarrhoea, vomiting, excessive sweating (has half Na as plasma)
  - Diabetes insipidus

- **Isotonic expansion**
  - Cardiac failure
  - Hypoalbuminemia

- **Hypotonic expansion**
  - Glomerular dysfunction (water retention), ADH excess

- **Hypertonic expansion**
  - Conn’s and cushing’s syndrome (mineralocorticoid excess)
SODIUM:

DISTRIBUTION:

TOTAL - 3000 mmol/l
Free ions - 70% major in ECF.
Complexed in bone - 30%

BALANCE:

Input - 100-200 mmol/24 hr.
Loss - < 10 mmol/24hr
REGULATION OF SODIUM BALANCE

- RENAL REGULATION:
  - GFR
    - ACTIVE REABSORPTION – PCT-70%
    - ALDOSTERONE - DCT <5%
  - ATRIAL NATRIURETIC PEPTIDE:
    - DECREASES DISTAL TUBULAR REABSORPTION
    - DECREASES RENIN SECRETION
Conservation of sodium by the different segments of the nephron

Proximal tubule
- 67%
- 16,800 mEq/day

Distal tubule
- 5%
- 1260 mEq/day

Cortical collecting duct

Collecting duct
- 3%
- 750 mEq/day

Thick ascending limb
- 25%
- 6300 mEq/day

Inner medullary collecting duct

Urine Flow = 1500ml/day
Urine Na Conc = 100mEq/L
Approx 0.6 % of filtered load excreted
Or 99.4% reabsorbed
HYPONATREMIA

NORMAL/HIGH
PL. OSMOLALITY

LOW PLASMA OSMOLALITY

TRANSLOCATIONAL
- GLUCOSE
- MANNITOL
- MALTOSE

PSEUDO HYPONATREMIA
- PROTEIN
- LIPID

URINE OSMOLALITY

<100mosm/kg
- WATER INTAKE EXCEEDS URINARY DILUTION
- LOW SOLUTE INTAKE
- CORRECTION PHASE OF HYPONATREMIA

>100mosm/kg

HYPOVOLEMIA
TBW TOTAL BODY Na

URINARY Na >20mmol/L
- DIURETIC EXCESS
- MINERALOCORTICOID DEF
- PROXIMAL RTA

EUVOLEMIA
TBW NO CHANGE IN TOTAL BODY Na

URINARY Na <10mmol/L
- VOMITTING
- DIARRHOEA
- BURNS
- SWEATING

HYPERVOLEMIA
TBW TOTAL BODY Na

URINARY Na >20mmol/L
- GLUCOCORTICOID DEF
- HYPOTHYROIDISM
- DIURETICS
- SIADH

URINARY Na <10mmol/L
- ACUTE / CHRONIC RENAL FAILURE
- PREGNANCY
- NEPHROTIC SYNDROME
- CIRRHOSIS
- HEART FAILURE
HYPERNATREMIA

ASSESS VOLUME

HYPOVOLEMIA
T  B  W
T  B  Na

HYPOVOLEMIA
T  B  W
T  B  Na

EUVOLEMIA
T  B  W
T  B  Na
NO CHANGE

EUVOLEMIA
T  B  W
T  B  Na
NO CHANGE

HYPERVOLEMA
T  B  W
T  B  Na

HYPERVOLEMA
T  B  W
T  B  Na

URINARY Na > 20 mmol/L

URINARY Na < 20 mmol/L

RENAL LOSS
1) OSMOTIC /LOOP DIURETIC
2) POST OBSTRUCTION
3) INTRINSIC RENAL DISEASE

EXTRA RENAL LOSS
1) DIABETES INSIPIDUS
2) BURNS
3) DIARRHOEA

RENAI losses
1) DIABETES INSIPIDUS
2) BURNS
3) DIARRHOEA

EXTRA RENAL LOSS
1) DIABETES INSIPIDUS
2) BURNS
3) DIARRHOEA

INSENSIBLE LOSS

EXTRA RENAL LOSS
1) DIABETES INSIPIDUS
2) BURNS
3) DIARRHOEA

INSENSIBLE LOSS

PRIMEIARY HYPERALDOSTERONISM
CUSHING
HYPERTONIC DIALYSIS

URINARY Na > 20 mmol/L

URINARY Na > 20 mmol/L

PRIMEIARY HYPERALDOSTERONISM
CUSHING
HYPERTONIC DIALYSIS

POTASSIUM:
PREDOMINANT INTRACELLULAR ION

DISTRIBUTION:
FREE - 90%
BOUND FORM – 10%
ECF - 2%

REGULATION:
RENAL:
REABSORPTION – PROXIMAL TUBULES
SECRETION – DISTAL TUBULE - ALDOSTERONE

GIT:
SECRETED IN GASTRIC JUICE
REABSORBED – SMALL INTESTINE
SECRETED – COLON – ALDOSTERONE
# Table 29-1

Factors That Can Alter Potassium Distribution Between the Intra- and Extracellular Fluid

<table>
<thead>
<tr>
<th>Factors That Shift $K^+$ into Cells (Decrease Extracellular $[K^+]$)</th>
<th>Factors That Shift $K^+$ Out of Cells (Increase Extracellular $[K^+]$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin</td>
<td>Insulin deficiency (diabetes mellitus)</td>
</tr>
<tr>
<td>Aldosterone</td>
<td>Aldosterone deficiency (Addison’s disease)</td>
</tr>
<tr>
<td>$\beta$-adrenergic stimulation</td>
<td>$\beta$-adrenergic blockade</td>
</tr>
<tr>
<td>Alkalosis</td>
<td>Acidosis</td>
</tr>
<tr>
<td></td>
<td>Cell lysis</td>
</tr>
<tr>
<td></td>
<td>Strenuous exercise</td>
</tr>
<tr>
<td></td>
<td>Increased extracellular fluid osmolarity</td>
</tr>
</tbody>
</table>
CHLORIDE

- MAJOR ANION OF ECF.
- SECRETED IN GASTRIC JUICE
- 99% REABSORBED UNDER NORMAL PH CONDITIONS.
- CHLORIDE SHIFT
- DECREASED IN ACIDOSIS
BICARBONATE

- PRESENT IN ECF
- BUFFERING ACTION
- REABSORBED IN TUBULE AS CO2 FOR HYDROGEN ION.
CALCIUM

- CALCITONIN - decreases bone resorption

Figure 29-10

Compensatory responses to decreased plasma ionized calcium concentration mediated by parathyroid hormone (PTH) and vitamin D.
REGULATION OF RENAL PHOSPHATE EXCRETION

PTH play important role in regulating phosphate concentration through 2 effects:

1) PTH promotes bone resorption, thereby dumping large amounts of phosphate ions into the ECF from bones salts

2) PTH decreases the transport maximum for phosphate by the renal tubules
Control of Renal Magnesium Excretion and Extracellular Magnesium Ion Concentration

Total plasma magnesium concentration is about 1.8 mEq/L, more than one half bound to plasma proteins.

Regulation of magnesium excretion is achieved by mainly changing tubular reabsorption.
PRECAUTIONS

COLLECTION OF BLOOD
STORAGE
TIME OF ANALYSIS
HEMOLYSIS
### Normal Laboratory Values

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>135-145 meq/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>3.5-5.0 meq/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>95-105 meq/L</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>22-28 meq/L</td>
</tr>
<tr>
<td>Calcium</td>
<td>9-11 mg/dL or 2.2-2.6 mmol/l (mmol/l*4=mg/l)</td>
</tr>
<tr>
<td>Phosphate</td>
<td>3.2-4.3 mg/dL or 0.8-1.4 mmol/l (mmol/l*3=mg/l)</td>
</tr>
<tr>
<td>Glucose</td>
<td>70-110 mg/dL (mg/dl/18=mmol/dl)</td>
</tr>
<tr>
<td>BUN</td>
<td>8-18 mg/dL or 3.3-6.7 mmol/l (mmol/l*6=mg/l)</td>
</tr>
<tr>
<td>Creatinine</td>
<td>0.6-1.2 mg/dL or 60-120 µmol/l (µmol/l*0.011=mg/dl)</td>
</tr>
<tr>
<td>PLASMA Osmolality</td>
<td>280-295 mOsm/kg</td>
</tr>
<tr>
<td>URINE Osmolality</td>
<td>50-1200 mOsm/kg</td>
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