Major intra and extracellular ions  Lec: 1

The body fluids are solutions of inorganic and organic solutes. The concentration balance of the various components is maintained in order for the cell and tissue to have a constant environment.

In order for the body to maintain this internal homeostasis, (homeostasis means maintenance of static or constant conditions in the internal environment) there are regulatory mechanisms which control pH, ionic balance, osmotic pressure etc. The volume and composition of the body fluids vary tremendously from one compartment to another, and are maintained remarkably constant despite the vicissitude of daily life and the stress imposed by disease.

Disturbance of fluid and electrolyte metabolism involve four properties of the body fluid-volume, osmolarity, hydrogen ion concentration (pH) and the concentration of other specific ions.

The total body water is divided into three compartments:

1) the intracellular compartment.
2) the extracellular compartment, which consists of the plasma and the interstitial fluid.
3) the transcellular compartment, which includes the fluid within the gastrointestinal tract, humor of the eye and the excretory system of the kidneys and glands, pericardial, peritoneal, synovial, cerebrospinal fluid.

All the body fluids intracellular, extracellular (interstitial, plasma or vascular) contains electrolytes. The electrolyte concentration varies in these fluids. These fluid compartments are separated from each other by membranes which are permeable to water and many organic and inorganic solutes. They are nearly impermeable to macromolecules e.g. proteins and selectively permeable to certain ions e.g. Na+, K+ and Mg+ as a result, each of these fluid compartments has distinct solute pattern and the solution in each compartment is ionically balanced.

The extracellular fluid contains large amounts of sodium, chloride and bicarbonate ions, plus nutrients for the cell such as oxygen, glucose, fatty acids and amino acids. The intracellular fluid contains large amounts of potassium, magnesium and phosphate ions.
The electrolyte balance of the body is maintained by a regulation between the intake and output of water. The intake of water includes the fluid taken orally and the release of water during the oxidation and other metabolic process in body. Water is eliminated from body by urine, expiration (lungs) and feces. Excessive loss of water results in concentration of body fluids which causes rise in osmotic pressure, as a result water moves out from intracellular compartment to maintain the osmotic pressure in extracellular fluid. This results in dehydration of cells. Loss of water above 20% may prove to be fatal.

The conc. of individual ions and their dosage are expressed by mEq/l rather than by weight/volume.

The conc. of the salts supplying the required ions will usually expressed as w/v.

Interconversion between mEq/l and w/v by the following equation:

\[
\text{mg of sub.}/l \times \frac{mwt}{Eq/mole} = \text{mEq/l}
\]

Example: calculate the no. Of mEq of NaCl in one liter of a 0.9% w/v solution.
Major Physiological Ions

1. **Calcium**
   About 99% of body calcium is found in bones and the remaining is present in extracellular fluid compartment.
   Only 10% of the ingested calcium is absorbed from the intestinal tract and the remainder is excreted with feces.
   The concentration of calcium in plasma averages about 9.4mg/dl, (9-10mg/dl), calcium level in plasma is regulated within narrow limits by parathyroid hormone.

   **The calcium in plasma is present in three forms**
   About 40% is combined with plasma proteins and is non diffusible through the capillary membrane.
   About 10% is combined with other substances of plasma and interstitial fluid (citrate, phosphate for instance) and is diffusible through the capillary membrane in such a manner that it is not ionized.
   The remaining 50% calcium present in plasma is diffusible through the capillary membrane and ionized. this ionic calcium does most of the functions of calcium in the body.

   **Calcium is important for:**
   1. blood clotting
   2. contraction of various smooth muscles.
   3. In cardiovascular system (CVS) Calcium is essential for contraction coupling in cardiac muscles as well as for the conduction of electric impulse in certain regions of heart.
   4. Calcium also plays role in maintaining the integrity of mucosal membrane, cell adhesion and function of the individual cell membrane as well.
   5. metabolic acidosis.
   6. kidney damage.
**Hypercalcemia causes:**
1. the nervous system is depressed, and the reflux action of CNS can become sluggish.
2. It also decreases the QT interval of the heart which can lead to cardiac arrhythmia.
3. It causes constipation and lack of appetite and depresses contractility of the muscle walls of the GIT.

**Hypocalcaemia occurs due to:**
1. hypoparathyroidism,
2. vitamin D deficiency,
3. Osteoblastic metastasis,
4. steatorrhea (fatty stools),
5. Cushing syndrome (hyper active adrenal cortex),
6. acute pancreatitis and acute hyperphosphatemia.

Change in blood pH can influence the degree of calcium binding to plasma proteins, with acidosis less calcium is bound to plasma proteins and cause hypocalcaemia.

When calcium ion concentration falls below normal, the excitability of the nerve and muscle cells increases markedly.

2. **Sodium**
The sodium and its associated anions, mainly chloride, account for more than 90% of the solute in extracellular fluid compartment.
The concentration of sodium is 142mEq/l in extracellular fluid, and 10 mEq/l in intracellular fluid.
Plasma sodium is a reasonable indicator of plasma osmolarity under many conditions.
Hyponatremia: can result from loss of sodium chloride from the extracellular fluid. **Conditions that cause hyponatremia owing to loss of sodium chloride include**: 1. excessive sweating, 2. diarrhea and vomiting, 3. and over use of diuretics that inhibit kidney to conserve sodium, 4. Addison’s disease, which results from decreased secretion of hormone aldosterone.

Hypernatremia: can be due to: excessive water loss from extracellular fluid, as in ADH deficiency, 2. secretion of sodium-retaining hormone aldosterone (cushing syndrome), excessive treatment with sodium salts.

3. Potassium
Potassium is a major intracellular cation present in a concentration approximately 23 times higher than the concentration of potassium present in Extracellular fluid compartment (about 95% in the cells and only 2% in extracellular fluid).
Extracellular fluid potassium concentration is normally precisely regulated at 4.2mEq/l. ,this is because many of the cell functions are sensitive to change in the extracellular fluid potassium concentration.

Maintenance of potassium balance depends primarily on its excretion by kidney because only 5-10 percent is excreted in faeces. Both, elevated and low levels of potassium, can be fatal, **Hyperkalemia** occurs due to high intake of potassium or in kidney damage, increase in potassium concentration can cause cardiac arrhythmias and lead to cardiac arrest by fibrillation while **Hypokalemia** due to vomiting, diarrhea, burns, diabetic coma, over use of thiazide diuretics, alkalosis etc.
4. Chloride
Chloride major extracellular anion is principally responsible for maintaining proper hydration, osmotic pressure, and normal cation anion balance in vascular and interstitial compartment.
The concentration of chloride is 103mEq/l in extracellular fluid, and 4 mEq/l in intracellular fluid.
Chloride ion has no pharmacological activity, used as a urinary acidifier.

**Decreased chloride concentration can be the result of:**
1. salt losing nephritis, leading to lack of tubular reabsorption of chloride,
2. metabolic acidosis such as found in diabetes mellitus,
3. in renal failure and
4. prolonged vomiting.

**Increased concentration of chloride may be due to:**
1. dehydration,
2. decreased renal blood flow found with congestive heart failure (CHF) or
3. excessive chloride uptake.

5. Phosphate
Phosphate is the principal anion of intracellular fluid compartment.
Inorganic phosphate in the plasma is mainly in two forms HPO4-- and H2PO4-- , the concentration of HPO4-- is 1.05 mmole/L and the concentration of H2PO4-- 0.26 mmole/L.
When the total quantity of the phosphate in extracellular fluid rises so does the concentration of each of these ions.

When pH of the extracellular fluid becomes more acidic there is relative increase in H2PO4- and decrease in HPO4- and vice versa.
Phosphorous is essential for:
1. proper metabolism of calcium,
2. normal bone and tooth development.
3. HPO4-- and H2PO4-- makes an important buffer system of body.
• **Hyperphosphatemia can be found in**: hypervitaminosis D, renal failure, and in hypoparathyroidism.

• **Hypophosphatemia can be due to**: vitamin D deficiency, hyperparathyroidism, and possible long term aluminum hydroxide antacid therapy.

6. **Bicarbonate**

Bicarbonate is the second most prevalent anion in extracellular fluid compartment. Along with carbonic acid it acts as body’s most important buffer system. When there is reduction in the extracellular fluid hydrogen ion concentration (alkalosis) the kidneys fail to reabsorb all the filtered bicarbonate thereby increasing the excretion of bicarbonate because bicarbonate ions normally buffer hydrogen in the extracellular fluid.

This loss of bicarbonate is as good as adding a hydrogen ion to the extracellular fluid. Therefore, in alkalosis, the removal of bicarbonate ions raises the extracellular fluid hydrogen ion concentration back towards normal.

In acidosis the kidneys do not excrete the bicarbonate in the urine but reabsorb all the filtered bicarbonate and produces new bicarbonate which is added back to the extracellular fluid. This reduces the extracellular fluid hydrogen ion concentration back towards normal.

7. **Magnesium**

Magnesium is the second most plentiful cation in the intracellular fluid. About 50% of total body magnesium is combined with calcium and phosphates in bones. Essential component of many enzymes involving phosphate metabolism. Also used in functioning of neuromuscular system.

Magnesium has a definite pharmacologic action; its salts when injected (im or iv) have powerful general anaesthetic action.
Soluble magnesium sulphate used for:
1. CNS depressant in obstetrics.
2. Convulsion states (has anticonvulsant activity).
3. Symptoms of tetanus.
Due to slow absorption of magnesium orally so used as saline cathartic (laxative).