

Major Intra and Extra Cellular Electrolytes

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Bicarbonate(HCO_3^-)

Replacement Therapy:

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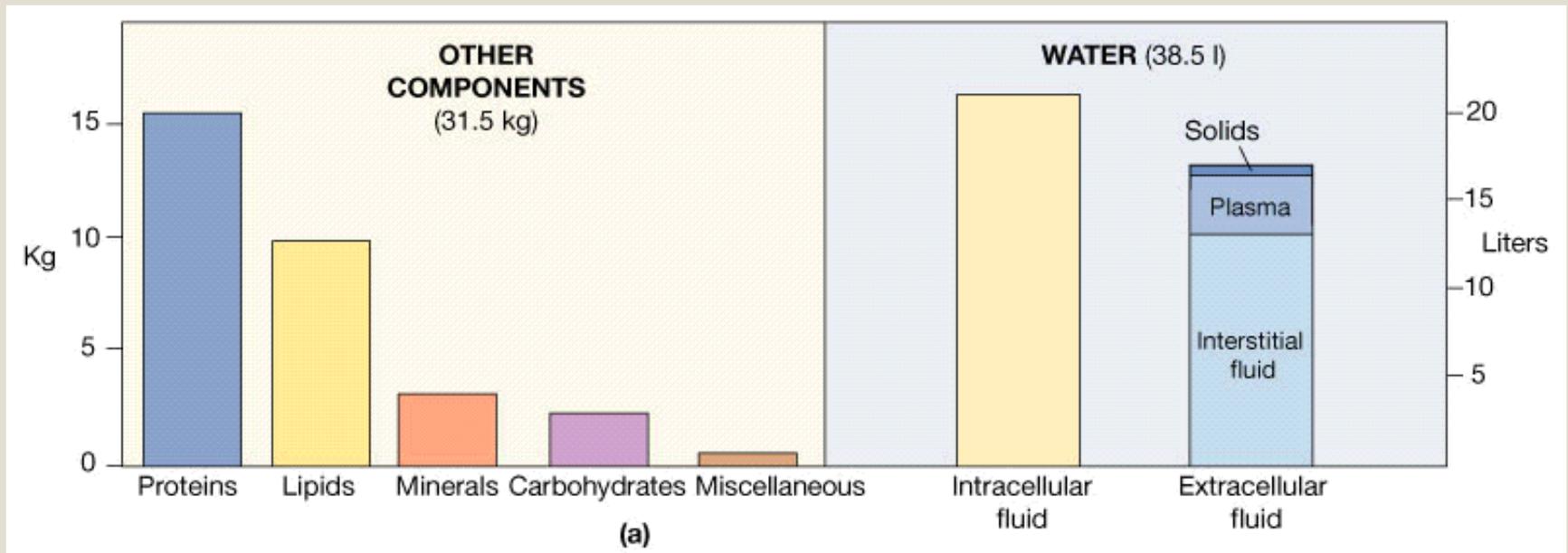
Physiological acid base balance

**Factors altering the pH of Extra Cellular
Fluid Electrolyte Combination Therapy**

Introduction

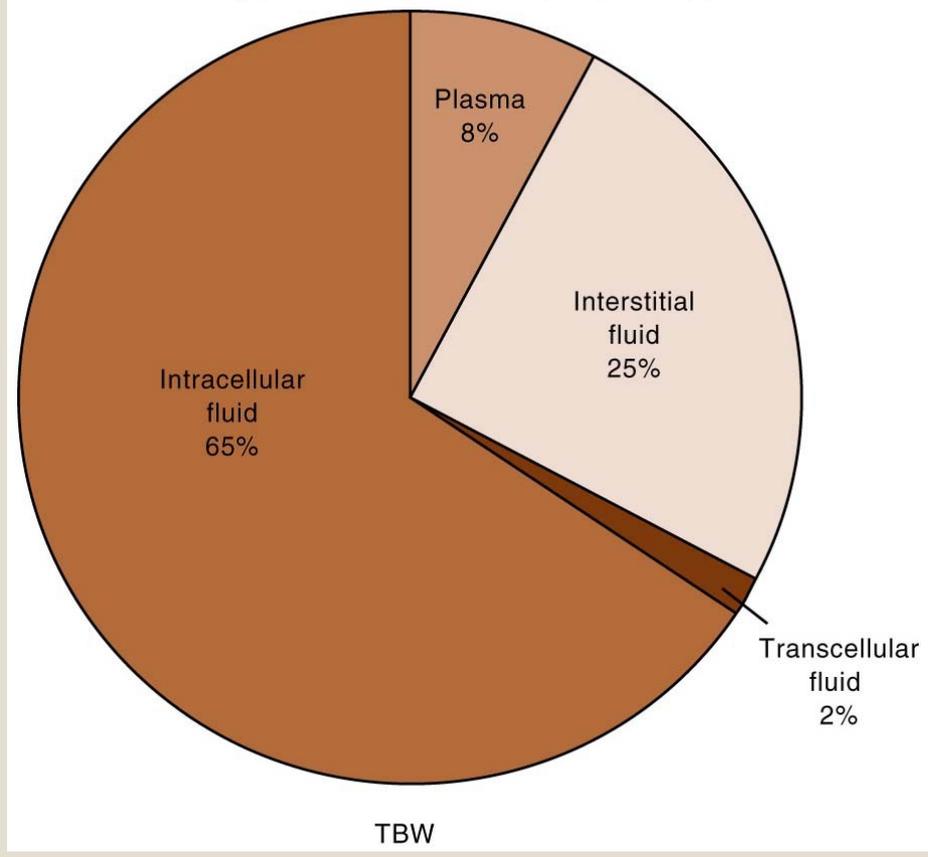
- Body consists of 70% water
 - Intracellular water (fluid inside cells) **ICF**
 - Extracellular water (fluid is outside the cells i.e. within interstitial tissues surrounding cells, blood plasma, and lymph) **ECF**
 - 2/3 of body weight is H₂O
 - 1/3 of H₂O is within cells
 - 1/3 of H₂O is extracellular in tissues surrounding cells
 - 25 % interstitial fluid (ISF)
 - 5- 8 % in plasma (IVF intravascular fluid)
 - 1- 2 % in transcellular fluids – CSF, intraocular fluids, serous membranes, GIT, respiratory and urinary tracts

The Composition of the Human Body

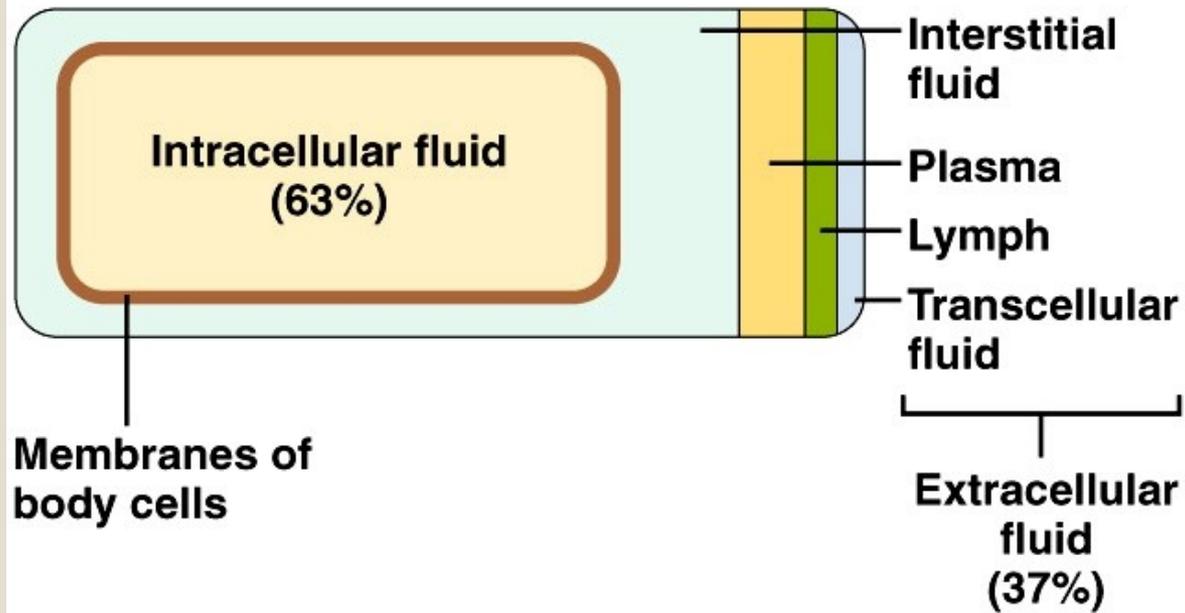


Total body water:

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Total body water



Major Compartments for Fluids

INTRACELLULAR FLUID (ICF): Inside cell

Most of body fluid here - 63% weight

Decreased in elderly

EXTRACELLULAR FLUID (ECF): Outside cell

a. Intravascular fluid - within blood vessels (5%)

b. Interstitial fluid - between cells & blood vessels
(15%)

c. Transcellular fluid - cerebrospinal, pericardial and
synovial fluid.

ELECTROLYTES

Substance when dissolved in solution separates into ions & is able to carry an electrical current

Cation - positively charged electrolyte e.g. Ca^{++}

Anion - negatively charged electrolyte e.g. Cl^-

No of Cations must equal to no of Anions for homeostasis to exist in each fluid compartment

ELECTROLYTES IN BODY FLUID COMPARTMENTS:

Intracellular: K, Mg, P

Extracellular: Na, Cl, HCO_3^-

- **Differences in concentration** of ions on different sides of the cell membrane result from **metabolic activity** of the cell
- Amount of **K** in the body determines the **volume of ICF** as the chief intracellular cation
- Amount of **Na** in the body determines the **volume of ECF** as the chief extracellular cation
- In electrolyte disturbances: primary concern is the concentration of various ions and the interrelation of positively and negatively charged ions with one another than the actual number.

Units of concentration of electrolytes

Expressed in units that define ability to combine with other ions

Equivalent weight: molecular weight of substance in grams divided by valence

- 1 equivalent weight dissolved in a liter solvent = equivalent per liter (1Eq/L)
- H_2SO_4 molar mass of 98 g mol^{-1} , and supplies two moles of H ions per mole of H_2SO_4 , so its equivalent weight is $98 \text{ g mol}^{-1}/2 \text{ eq mol}^{-1} = 49 \text{ g eq}^{-1}$.
- Units expressed in milli equivalents per liter (1000 mEq = 1Eq)

Disturbances of H₂O balance

Dehydration: most common

Inadequate intake of water, diarrhea or vomiting

Excess H₂O loss, comatose or debilitated patients

Over-hydration: less common

- Excessive fluid intake when renal function is impaired, renal disease; excessive administration of IV fluids
- Conditions that produce H₂O imbalance also disturb electrolyte composition
- Most result from depletion of body electrolytes

Depletion of electrolytes

- Vomiting or diarrhea: Na and K depletion
- Excessive use of diuretics
- Excessive diuresis in diabetic acidosis
- Renal tubular disease

ELECTROLYTES

Na⁺: most abundant electrolyte in the body, chem. and osmotic gradient, osmosis, heart function and cell memb etc.

K⁺: essential for normal **membrane excitability** for nerve impulse

Cl⁻: regulates **osmotic pressure** and assists in regulating acid-base balance

Ca²⁺: usually combined with P to form the mineral salts of **bones and teeth**, promotes **nerve impulse** and **muscle contraction/relaxation**.

Mg²⁺: plays role in **carbohydrate** and **protein metabolism**, **storage** and use of **intracellular energy** and **neural transmission**. Important in the functioning of the **heart, nerves, and muscles**.

SODIUM/CHLORIDE IMBALANCE

- Regulated by the **kidneys**
- Influenced by the hormone **aldosterone**
- **Na** is responsible for **water retention** and serum **osmolarity** level
- Chloride ion frequently appears with the sodium ion
- Normal Na = 135-145 mEq/L
- Chloride 95-108 mEq/L
- Na and Cl are concentrated in ECF

Chloride

- Maintains **serum osmolarity** along with Na
- Helps to maintain **acid/base balance**
- Combines with other ions for **homeostasis**; sodium, hydrochloric acid, K, Ca
- Closely tied to Na
- **Decreased** level is most commonly due to **GI losses**

Functions of Sodium

- Transmission and conduction of **nerve impulses**
- Responsible for **osmolarity** of vascular fluids
- Regulation of **body fluid levels**
- Na shifts into cells and K shifts out of the cells (**sodium pump**)
- Assists with regulation of **acid-base balance** by combining with Cl or HCO_3 to regulate the balance

Functions of Chloride

- Found in **ECF**
- Changes the **serum osmolarity**
- Goes with Na in **retention of water**
- Assists with regulation of **acid-base** balance
- Cl combines with H to form **HCl** in **stomach**

Hyponatremia

- Excessive sodium loss or H₂O gain
- CAUSES
 - Prolonged diuretic therapy
 - Excessive diaphoresis
 - Insufficient Na intake
 - GI losses - laxatives, vomiting
 - Administration of hypotonic fluids
 - Compulsive water drinking
 - Labor induction with oxytocin
 - Cystic fibrosis
 - Alcoholism

Symptoms

- Headache
- Faintness
- Confusion
- Muscle cramping/twitching
- Increased weight
- Convulsions

Hyponatremia

- Assessment

- Monitor sign & symptoms in patients at risk
 - ▢ Muscle weakness
 - ▢ Tachycardia
 - ▢ Fatigue
 - ▢ Apathy
 - ▢ Dry skin, pale mucus membranes
 - ▢ Confusion
 - ▢ Headache
 - ▢ Nausea/Vomiting, Abdominal cramps
 - ▢ Orthostatic hypotension

Treatment

- Restrict fluids
- Monitor serum Na levels
- IV normal saline or Lactated Ringers
- If Na is below 115, mEq/L hypertonic saline is administered
- May given a diuretic to increase H₂O loss
- Encourage a balanced diet
- Safety for weakness or confusion
- Assist with ambulation if low B.P.

Hypernatremia

Occurs with excess loss of H₂O or excessive retention of Na

- Can lead to death if not treated
- Causes
 - Vomiting/diarrhea
 - Diaphoresis
 - Inadequate ADH
 - Some drugs
 - Hypertonic fluids
 - Major burns
- Sign/Symptoms
 - Thirst
 - Flushed skin
 - Dry mucus membranes
 - Low urinary output
 - Tachycardia
 - Seizures
 - Hyperactive deep tendon reflexes

Treatment of Hypernatremia

- Low Na diet
- Encourage H₂O drinking
- Monitor fluid intake on patients with heart or renal disease
- Observe changes in B.P. and HR if hypovolemic
- Monitor serum Na levels
- Weigh monitoring

Potassium Imbalances

- K is the most abundant cation in the body cells
 - 97% is found in the ICF, plentiful in the GIT
 - Normal extracellular K^+ is 3.5-5.3
 - Serum K^+ level below **2.5** or above **7.0** can cause **cardiac arrest**
 - 80-90% is excreted through the kidneys
 - **Functions**
 - Promotes conduction and transmission of **nerve** impulses
 - Contraction of **muscle**
 - Promotes **enzyme** action
 - Assist in the maintenance of **acid-base** balance
- Food sources** - veggies, fruits, nuts and meat

Hypokalemia

Low potassium level

- Causes
 - Prolonged diuretic therapy
 - Inadequate intake
 - Severe diaphoresis
 - Use of laxative, vomiting
 - Excess insulin
 - Excess stress
 - Hepatic disease
 - Acute alcoholism

Signs and Symptoms of hypocalcemia

- Anorexia
- Nausea, vomiting
- Drowsiness, lethargy, confusion
- Leg cramps
- Muscle weakness
- Hyperreflexia (overactive or overresponsive reflexes).
- Hypotension
- Cardiac dysrhythmias
- Polyuria

Hyperkalemia

- Higher than normal levels of K
- Decreased pH(**acidosis**)
- Results form impaired renal function
- Metabolic acidosis
- Acts as myocardial depressant; decreased heart rate, cardiac output
- Muscle weakness
- GI hyperactivity

Etiology

- Increased dietary intake
- Excessive administration of K^+
- Excessive use of salt substitutes
- Widespread cell damage, burns, trauma
- Administration of larger quantities of blood that is old
- Renal failure

Signs and Symptoms

- Apathy
- Confusion
- Numbness/ paresthesia of extremities
- Abdominal cramps
- Nausea
- Flaccid muscles
- Diarrhea
- Oliguria
- Bradycardia
- Cardiac arrest

Calcium

- About 99% of body Ca is found in **bones** and the remaining is present in **ECF**.
- It is important for blood **clotting** and contraction of various **smooth muscles**.
- In cardiovascular system (CVS) Ca is essential for **contraction** coupling in cardiac muscles as well as for the conduction of **electric impulse** in certain regions of heart.
- It plays role in maintaining **the integrity of mucosal membrane, cell adhesion** and **function** of the individual cell membrane as well.

Physiological role of Calcium

Calcium is found mainly in the ECF whilst P is found mostly in the ICF.

Both are important in the maintenance of healthy bone and teeth.

Ca is also important in the transmission of nerve impulses across synapses, the clotting of blood and the contraction of muscles. If the levels of **Ca fall** below normal level both muscles and **nerves become more excitable.**

Calcium

Regulated by the parathyroid gland

Parathyroid hormone

- Helps with calcium retention and phosphate excretion through the kidneys
- Promotes calcium absorption in the intestines
- Helps mobilize calcium from the bone

Hypercalcemia:

- When the level of Calcium **rises** above normal, (Hypercalcemia) Increased serum levels of Ca^{++}
- the nervous system is depressed, and the reflex action of CNS can become sluggish.
- It also **decreases** the **QT** interval of the heart which can lead to cardiac arrhythmia.
- It causes constipation and lack of appetite and depresses contractility of the muscle walls of the GIT.

Hypercalcemia:

- The depressive effect begins to appear when blood Calcium level rises above 12mg/dl and beyond 17 mg/dl CaPO_4 crystals are likely to ppt throughout the body.

This situation occurs due to hypoparathyroidism, vit D deficiency, Osteoblastic metastasis, steatorrhea (fatty stools), Cushing syndrome (hyper active adrenal cortex), acute pancreatitis and acute hypophosphatemia.

Signs and Symptoms

- Muscle weakness
- Personality changes
- Nausea and vomiting
- Extreme thirst
- Anorexia
- Constipation
- Polyuria
- Pathological fractures
- Calcifications in the skin and cornea
- Cardiac arrest

Hypocalcemia:

- Change in blood pH can influence the degree of calcium binding to plasma proteins. With acidosis less calcium is bound to plasma proteins.
- When calcium ion concentration falls below normal, the excitability of the nerve and muscle cells increases markedly.

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.

- Hypochloremia:

(Decreased chloride concentration):

- It can be the result of
 - salt losing nephritis, leading to lack of tubular reabsorption of chloride,
 - metabolic acidosis such as found in diabetes mellitus,
 - in renal failure and
 - prolonged vomiting.

● Hyperchloremia:

(Increased concentration of chloride):

may be due to

- dehydration,
- decreased renal blood flow found with congestive heart failure (CHF) or
- excessive chloride intake.

Phosphate

- It is principal anion of ICF compartment.
- Inorganic phosphate in the plasma is mainly in two forms
 - i) HPO_4^- (hydrogen phosphate) and
 - ii) H_2PO_4^- (dihydrogen phosphate)
- The concentration of HPO_4^- is 1.05 mmole/L and
- the concentration of H_2PO_4^- 0.26 mmole/L.
- When the total quantity of the phosphate in ECF rises so does the concentration of each of these ions.

When pH of the ECF becomes more acidic there is relative increase in H_2PO_4^- and decrease in HPO_4^{2-} and vice versa.

- P is essential for proper metabolism of calcium, normal bone and tooth development.
- HPO_4^- and H_2PO_4^- makes an important buffer system of body.

Bicarbonate

- It is the second most prevalent anion in ECF. Along with carbonic acid it acts as body's most important buffer system.
- Each day kidney filters about 4320 milliequivalents of bicarbonate and under normal conditions all of this is reabsorbed from the tubules, thereby conserving the primary buffer system of the extracellular fluid.
- When there is reduction in the ECF 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 ECF hydrogen ion concentration back towards normal.

- In acidosis the kidneys reabsorb all the filtered bicarbonate and produces new bicarbonate which is added back to the ECF.

This reduces the ECF H^+ concentration back towards normal.
i.e. reverse of acidosis since HCO_3^- is alkaline