

Fluid and Electrolytes

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Outline

- Fluid and Electrolytes, Normal
- Disturbances of fluid and electrolytes
- Disturbances of acid-base balance

Fluid, Electrolyte and Acid-Base Balance

- **Body fluid** is composed primarily of **water**, which contains chemical compounds called **electrolytes**.
- Normal body function depends on a relatively constant volume of water and definite concentration of chemical compounds (electrolyte)
- From 45% to 80% of body weight is fluid; the variation depends on body **fat, gender, and age**.

Cont...

- Water is the most essential nutrient of life. 60-65% of the body weight is water.
- Electrolyte is a chemical compound that dissociate in a solution to break up into separate electrically charged particles (ions)
- Cations: positively charged ions (Na^+ , K^+ , Ca^{++})
- Anion: negatively " " (Cl^- , HPO_4^-)

Fluid Compartments

- There are two major fluid compartments
- **Intracellular Fluid Compartment (ICFC)**; the compartment in which the fluids **with in the body cells** are accompanied.
- **Extracellular fluid compartment (ECFC)**; the compartment which consists of **all fluid out side the cells**.
- ECF divided in to the **intravascular fluid**, which consists of the fluid inside the blood and lymphatic vessels, & **interstitial fluid**, which is the fluid between the cells.

Cont...

- Adults have about $\frac{2}{3}$ of their total fluid within the intracellular compartment and $\frac{1}{3}$ in the extracellular compartment.
- In contrast, newborns have more extracellular than intracellular fluid. But this composition reverses when the newborn grows up.

Distribution of body water in adults

- Body water is contained in the two compartments
- ICF - about 40% of body weight (25 liter)
- ECF - about 20% of body weight (20 liter) in which:
 - 5 liter in intra vassal
 - 15 liter in interstitial -tissue space: the space between blood and the cells
- Apart from this the ECF contains other fluids, which are usually **negligible**, considering their concentration in the body. These are **CSF, ocular fluid, synovial fluid, pleural fluid, pericardial fluid, and peritoneal fluid.**

Pressures affecting fluid and electrolyte movement

The most important pressures involved in fluid movement are **osmotic pressure and hydrostatic pressure.**

- 1.Osmotic pressure: the** force of attraction for water by undissolved particles helps to keep fluid with in blood vessels and oppose net flow outward. Plasma proteins contribute to the osmotic pressure because those are hydrophilic (colloid oncotic pressure)
- 2.Hydrostatic pressure :** promotes filtration of fluid from an area of higher pressure to an area of lower pressure (from the blood vessels in to the interstitial fluid)

Cont...

- **Filtration pressure**= hydrostatic pressure- osmotic pressure
- In the arterioles $FP=HP-OP = 32-22 \text{ mmHg} = 10 \text{ mmHg}$ (Fluid filters out of the vessels in to interstitial fluid)
- In the venule $FP = HP-OP = 12-22 \text{ mmHg} = -10\text{mmHg}$ (Fluid filters from the interstitial fluid back to the venous capillaries and venules)
- This is a continuous and balanced process so that almost all filtered fluid is returned to the vascular space.
- If the HP is greatly increased or the OP is greatly reduced, some of the filtered fluid remains in the interstitial space ,and this accumulation is called **edema**
- Fluid intake, food intake, and electrolyte output and hormonal control are factors affecting fluid and electrolyte balance.

Electrolyte composition of the fluid

• Electrolytes	ICF	ECF
• K^{+}	141mEq /L	4mEq/L
• Mg^{++}	58mEq/L	2mEq/L
• $HPo4^{-}$	75mEq/L	10mEq/L
• Na^{+}	10mEq/L	140mEq/L
• Cl^{-} 103mEq/L	4mEq/L	

COMPOSITION AND DISTRIBUTION OF BODY FLUIDS

- **Water** constitutes **50-70% of TBWt**
- It depends on **age, sex, fat** distribution in the body.
 - Full term **infant** has **75-80%** TBWt
 - **Young adulthood** = 60% of TBWt
 - **Old age male** = 50%
 - Young **female** = 50%
 - **Old age female** = 40%
 - **Obesity** = 30-40%

- The **body water** is divided into two functional compartments, the **ECF** and **ICF**
 - **ECF** is 1/3 of TBW, composed of **plasma** (5%), and **interstitial** fluid(15%)
 - **ICF** is 2/3 of TBW, constitutes the fluid **inside the cell**
- **ECF** – main cation is sodium **Na⁺** and the main anions are **chloride** and **bicarbonate**

- **ICF-** the principal cation is **potassium** and **magnesium**, while **phosphate** and negatively charged **proteins** are main anions
- This composition maintained, manipulated by **Na⁺-K⁺ pump**, the cell membrane, **hydrostatic pressure**, **oncotic pressure**
- Although movement of solutes and ions is restricted between the fluid compartments water moves freely(osmosis).

CHEMICAL COMPOSITION OF FLUID COMPARTMENT

154 mEq/L 154 mEq/L

CATIONS		ANIONS	
Na ⁺	142	Cl ⁻	103
		HCO ₃ ⁻	27
		SO ₄ ⁼⁼	3
		PO ₄ ⁼⁼	
K ⁺	4		
Ca ⁺⁺	5	Organic Acids	5
Mg ⁺⁺	3	Protein	16

11/17/25 PLASMA

153 mEq/L 153 mEq/L

CATIONS		ANIONS	
Na ⁺	144	Cl ⁻	114
		HCO ₃ ⁻	30
		SO ₄ ⁼⁼	3
		PO ₄ ⁼⁼	
K ⁺	4		
Ca ⁺⁺	3	Organic Acids	5
Mg ⁺⁺	2	Proteins	1

INTERSTITIAL FLUID

200 mEq/L 200 mEq/L

CATIONS		ANIONS	
K ⁺	150	HPO ₄ [≡]	150
		SO ₄ ⁼⁼	
		HCO ₃ ⁻	10
Mg ⁺⁺	40	Protein	40
Na ⁺	10		

INTRACELLULAR FLUID

Table 2-11 Electrolyte Solutions for Parenteral Administration

Solution	Electrolyte Composition (mEq/L)						
	Na	CL	K	HCO ₃ ⁻	Ca	Mg	mOsm
Extracellular fluid	142	103	4	27	5	3	280–310
Lactated Ringer's	130	109	4	28	3		273
0.9% Sodium chloride	154	154					308
D ₅ 0.45% Sodium chloride	77	77					407
D ₅ W							253
3% Sodium chloride	513	513					1026

Commonly available replacement fluids

	Ions (millimol per liter)			Carbohydrate (gram per liter)	Used for replacement of
Fluid	Na ⁺	Cl	Ka ⁺		
Physiologic saline (Normal saline)	154	154	0	0	Blood/ extra cellular fluid loss
Hartmann's solution (Ringer's lactate) (Contains lactate and calcium)	131	112	5	0	Blood, intracellular fluid loss
5% glucose in water (D/W)	0	0	0	50	Maintenance and for medication

Sources of water gain and lose

Sources of Body Water Gains and Losses in the Adult

Gains		Losses	
Oral intake		Urine	1500 mL
As water	1000 mL	Insensible losses	
In food	1300 mL	Lungs	300 mL
Water of oxidation	200 mL	Skin	500 mL
		Feces	200 mL
Total	2500 mL	Total	2500 mL

Disturbances of fluid and electrolytes

Classification

- Disturbances in body fluids can be classified into **three**:
 - Disturbance in **fluid volume**
 - Disturbance in **composition**
 - Disturbance in **acid base** balance

Disturbance in fluid volume

❖ *Volume deficit*

- Extra cellular fluid (**ECF**) volume deficit is the most common fluid volume disorder in the surgical patient.
- The lost fluid is not water alone, but **water** and **electrolytes** in approximately the same proportion as they exist in normal extra cellular fluid.

➤ **Causes**

- Bleeding
- Losses of gastro-intestinal fluids: e.g. vomiting, gastric tube, diarrhea and enterocutaneous fistulas
- Sequestration or loss of fluid in soft tissue injuries and infections such as burns
- Intra-abdominal and retroperitoneal inflammatory processes such as peritonitis, intestinal obstruction, etc.

➤ **Clinical feature**

- Depends on the severity of fluid loss
- ***Moderate (5-10%):*** *sleepiness, orthostatic hypotension*
- ***Severe (more than 15%):*** *signs of hypotension, stupor or coma, sunken eye balls, dry oral mucosa and tongue, poor skin turgor and decrease in body temperature.*

➤ Treatment

- Replacement of extra cellular loss with fluid of similar composition:
- *Blood loss: Replace with **Ringer's Lactate, Normal Saline** or **Blood**, if needed*
- *Extra cellular fluid: Replace with **Ringer's Lactate, Normal Saline***

➤ ***Rate of fluid replacement***

- The Rate depends on the **degree of dehydration**.
- It should be **fast** until the vital signs are corrected and adequate urine output is achieved.
- One liter over 30 minutes to one hour can be given for severe dehydration.

➤ ***Monitoring***

- The **general condition** and the **vital signs** of the patient should be followed.
- The **urine out put** should be monitored hourly.
- **Auscultate** the chest to follow overload especially in children and the elderly.

❖ Volume Excess

- Extra cellular fluid volume excess is generally **iatrogenic** or secondary to renal insufficiency, cirrhosis, or congestive heart failure.

➤ **Clinical feature**

- Subcutaneous edema, basilar rales on chest auscultation, distention of peripheral veins, and functional murmurs may be detected.
- Children, the elderly, patients with cardiac or renal problems are at increased risk of dangers of fluid replacement.

➤ **Treatment**

- Stop IV fluids (Fluid restriction)
- Diuretics: e.g. frusemide
- Follow the clinical condition.

Disturbance of Electrolytes

- ❖ Sodium
- ❖ Potassium
- ❖ Calcium
- ❖ Magnesium
- ❖ Chlorine
- ❖ Calcium

Sodium (Na⁺)

- It is the most abundant cation of the ECF.
- After trauma and surgery, there is a period of shut down of sodium excretion for up to 48 hours.
- During this period, it may not be advisable to administer large quantities of isotonic saline.

- The concentration of serum sodium is not related to the volume status of extracellular fluid.
- A severe volume deficit may exist with a normal low or high serum level.
- Daily requirement of sodium is one millimol/kg.
- The excretion of sodium by the kidneys is under the control of aldosterone.

Sodium depletion (Hyponatremia):

- Na⁺ less than 130 milliequivalent/liter
- **Hyponatremia** can be associated with
- ✓ **Volume depletion**, sodium and water depletion.
- Most frequent cause of sodium and water depletion in surgery is **small intestinal obstruction**.

- Duodenal, Biliary, pancreatic and high intestinal fistula are also causes of hyponatremia.
- ✓ **Water intoxication** with excess volume and edema, over-prescribing of intravenous 5% D/W and colorectal washouts with plain water

➤ **Clinical feature**

- It can present with signs and symptoms of either **fluid excess** or **fluid overload**
- depending on the primary cause.

➤ **Laboratory:**

- Serum sodium and other electrolytes, hematocrit drops

➤ **Treatment**

- Ringer's Lactate or Normal Saline In cases of volume depletion.
- Fluid restriction and sodium sparing diuretics In case of fluid excess.

Sodium Excess (Hypernatremia):

- Na⁺ more than 145 mmol

➤ **Causes**

- **Excessive water loss** in **burns** or **sweating**, insensible losses through the lungs.
- **Excess amount of 0.9% saline** solution is given IV during the early operative period where there is some degree of retention of sodium.

➤ **Clinical feature**

- Depending on the cause it can be of fluid excess or fluid deficit.

➤ **Treatment**

- 5% D/W can be infused slowly

Potassium (K⁺)

- Potassium is the most abundant intracellular cation.
- 98% of potassium is found intracellular with $\frac{3}{4}$ of the total body potassium in ***skeletal muscles***.
- The average daily requirement is 1 mmol/kg.

Potassium depletion (Hypokalemia):

- K + less than 3.5 millimol

➤ **Causes**

- 1. ***Loss in gastrointestinal secretions*** such as vomiting in GOO or diarrhea
- 2. ***Movement of potassium into cells*** e.g. in alkalosis
- 3. ***Prolonged administration of potassium free*** parenteral fluids with continued obligatory renal loss of potassium
- 4. ***Excessive renal excretion*** – e.g. Diuretic use.

➤ **Clinical features**

- Most patients are asymptomatic.
- Clinical symptoms and signs such as listlessness, slurred speech, muscular hypotonia, and depressed reflexes are presenting features.
- Abdominal distention results due to paralytic ileus.

➤ **Treatment**

- Oral potassium in the form of milk, meat extracts, fruit juices, honey and KCl tablets
40 mmol KCl IV added to 1 liter of fluid run over 6 -8 hours.
- Never directly IV.
- Correct the underlying cause
- N.B.: - Administration should be properly controlled, the level of potassium should be checked daily and the urine out put must be adequate.

Potassium Excess (Hyperkalemia):

- *K + more than 5 mmol*
- Significant quantity of intracellular potassium is released into the extra cellular space in response to severe injury, surgery, acidosis and a catabolic state.
- A significant rise in serum potassium concentration may occur in these states in the presence of oliguric or anuric renal failure.
- A renal insufficiency with hypoaldosteronism can
cause hyperkalemia.

➤ **Clinical features**

- Nausea, vomiting, intermittent intestinal colic and diarrhea are the presenting pictures.
- Cardiovascular signs are apparent on ECG with high peaked T waves, widened QRS complex and depressed ST segment.
- Disappearance of T waves, heart block and cardiac arrest may develop with increasing levels of potassium.

➤ Treatment

- Measures to reduce K⁺ level:
- Administration of **bicarbonate** and **glucose** with insulin.
- 10 to 20 units of regular insulin and 25 to 50 g of glucose can be used.
- 10 ml of 10% calcium gluconate to suppress the myocardial effect .
- Enteral administration of cation exchange resin
- Dialysis
- Avoid exogenous potassium

Calcium (Ca++)

- Normal serum level is 8.5 to 10.5 mg/dl.
- An increase in pH causes a fall in the ionized proportion of calcium.
- Calcium imbalance is not frequently encountered.
- **Hypocalcaemia**
- **Hypercalcaemia**

Hypocalcaemia

- *Serum level below 8mg/dl*
- Common causes include:
- Hypoparathyroidism after thyroid surgery
- Acute pancreatitis
- Massive soft tissue infection (necrotizing fascitis) and
- Pancreatic and small bowel fistulas

❖ **Clinical feature**

- *Latent hypocalcemia: Positive Chovestek's and Trousseau's sign.*
- *Symptomatic: Numbness and tingling, hyperactive tendon reflexes, muscle and abdominal cramp, tetany with carpopedal spasm and convulsions.*

❖ **Treatment**

- IV Calcium gluconate (10ml of 10% solution over 10 minute) or calcium chloride.
- Calcium lactate may be given orally with or without Vitamin D.

Hypercalcaemia

- *Serum calcium over 10.5mg/dl*
- Hypercalcaemia occurs with hyperparathyroidism, Vitamin D intoxication, cancer and prolonged immobilization.
- It is uncommon in surgical patients.

❖ **Clinical feature**

- Most are asymptomatic. Symptoms can include fatigue, lassitude, weakness of varying degree, anorexia, nausea and vomiting.
- Other symptoms include severe headaches, pain in the back and extremities, thirst, polydypsia and polyuria.

❖ **Treatment**

- A serum level of calcium of 15 mg/dl or higher requires emergency treatment.
- Vigorous volume repletion with salt solutions.
- Oral or IV inorganic phosphate or mithramycin.

Acid-Base balance/Disturbances

General concepts

- **Acid-base homeostasis** represents equilibrium among the concentration of H^+ , **partial pressure of CO_2 (PCO_2)**, and HCO_3^- .
- Clinically, **H^+ concentration** is expressed as **pH**.
- **Normal pH is 7.35 to 7.45.**
- The pH of body fluids is maintained within a **narrow range**
- The control of this tight balance is accomplished by:

Respiratory Acid-Base imbalance

Respiratory Acidosis	Respiratory Alkalosis
Hypoventilation.	Hyperventilation.
Accumulation of CO₂ in the tissues	Excessive loss of CO₂.
pH decreases	pH increases
Plasma HCO₃ increases.	Plasma HCO₃ decreases
PCO₂ increases	PCO₂ decreases

Acid Base Disorders

Respiratory acidosis:		Metabolic acidosis
Hypoventilation		Gain of fixed acid or loss of HCO_3
Accumulation of CO_2		Plasma HCO_3 decreases
pH decreases		pH decreases
Respiratory alkalosis		Metabolic alkalosis
Hyperventilation.		Loss of fixed acid or gain of HCO_3
Excessive loss of CO_2		Plasma HCO_3 increases
pH increases	mohammad siraj	pH increases

acidosis

respiratory acidosis due to alveolar hypoventilation accumulation of CO₂)

Possible causes: Respiratory depression, increased airway resistance impaired gas exchange (emphysema, fibrosis, muscular dystrophy, pneumonia)

Metabolic acidosis due to gain of fixed acid or loss of bicarbonate.

Possible causes: lactic acidosis, keto acidosis, Buffer capabilities exceeded once pH change appears in plasma.

11/11/25 *Options for compensation?*

- **Blood buffer**:- which includes the **bicarbonate** and **carbonic acid**, **phosphates**, **serum proteins** and **meth-hemoglobin**(play a greatest role from the blood buffers)
- **The lung**:- excretes **acid(CO₂)**
- **Kidney** :- the ultimate organ to maintain imbalance to near normal by its capacity to **excrete both acid and base**.

- **Acidemia** refers to pH of less than 7.35, and **alkalemia** refers to pH of greater than 7.45.
- **Acidosis** and **alkalosis** describe processes that cause the accumulation of **acid** or **alkali**, respectively.
- The terms **acidosis** and **acidemia** and the terms **alkalosis** and **alkalemia** are often used interchangeably, but such usage is **inaccurate**.
- A patient, for example, may be acidemic while alkalosis is occurring.

- ❖ **Laboratory studies** that are necessary for the initial evaluation of acid-base disturbances include
- ***arterial pH, arterial PCO_2 ($PaCO_2$) (normal is 35 to 45 mm Hg), and serum electrolytes [HCO_3^- (normal is 22 to 31 mmol/L)].***
 - Although base-excess or base-deficit calculations can be made, this information does not add substantially to the evaluation.

Compensatory response to primary disorders

- **Compensation** for acid-base derangements is either ***respiratory*** (for metabolic derangements) or ***metabolic*** (for respiratory derangements).
- Disorders that **initially alter PaCO_2** are termed ***respiratory acidosis or alkalosis***.
- Alternatively, disorders that **initially affect plasma HCO_3^- concentration** are termed ***metabolic acidosis or alkalosis***.

- **Primary metabolic disorders** stimulate ***respiratory responses*** that act to return the ratio of PCO_2 to HCO_3^- (and therefore the pH) toward normal.
- Similarly, **primary respiratory disturbances** elicit countervailing ***metabolic responses*** that also act to normalize pH.

- As a general rule, these compensatory responses do not normalize pH because to do so would remove the stimulus for compensation.
- By convention, these compensating changes are termed ***secondary, respiratory, or metabolic compensation*** for the primary disturbance.

Metabolic Alkalosis

- **Alkalosis (accumulation of Base or loss of acid)**
- **Causes**
- Loss of acid from the stomach by repeated vomiting or aspiration
- Excessive ingestion of absorbable alkali
- Hypokalemic alkalosis in patients with pyloric stenosis: potassium loss due to repeated vomiting.

➤ **Clinical Features**

- Cheyne-stokes respiration with periods of apnea
- Tetany sometime occurs.

➤ **Treatment**

- Repletion of ***volume + potassium*** (check urine output)
- Use of 0.1 N or 0.2 N HCl is also effective in treatment of resistant metabolic alkalosis.

Respiratory Alkalosis

- **PCO₂ below the normal range.**

➤ Causes

- Most common cause is ***excessive pulmonary ventilation*** by anesthetized patients in surgical practice.
- It can also be caused by hyperventilation due to severe pain, hyper pyrexia and high altitude.

➤ **Clinical Features**

- The dangers of a severe respiratory alkalosis are those related to ***potassium depletion*** and include the development of ventricular ***arrhythmias*** and ***fibrillation***.

➤ **Treatment**

- Can be corrected by breathing into a plastic bag, or insufflation of carbon dioxide.

Metabolic Acidosis

- **Acidosis (accumulation of acid or loss of base)**

➤ **Causes**

- ***Increase in fixed acids due to:***
 - Anaerobic tissue metabolism (shock, infection, tissue injury)
 - Retention of metabolites in renal insufficiency
 - Formation of ketone bodies in diabetes or starvation

- ***Loss of bases in:***

- Chronic diarrhea, gastro colic or high intestinal fistula, excess intestinal aspiration

- **Clinical Features**

- Besides signs and symptoms of the primary etiology like shock and infection, rapid, deep, noisy breathing is found.
- The urine becomes strongly acidic.

➤ **Treatment**

- Tissue hypoxia should be treated by **reperfusion**
- ***Sodium bicarbonate*** can be given where bases have been lost or where the degree of acidosis is so severe that myocardial function is compromised.

Respiratory Acidosis

➤ Causes

- *Impaired alveolar ventilation due to:*
 - Airway obstruction
 - Thoracic and upper abdominal incisions, abdominal distention in ileus
 - Pulmonary diseases (pneumonia, atelectasis especially post operative
 - Inadequate ventilation of the anesthetized patient

➤ **Clinical Features**

- Restlessness, hypertension and tachycardia may indicate inadequate ventilation with hypercapnia.

➤ **Treatment**

- Must focus on ***relieving the primary cause***.
- Relieving airway obstruction, adequate analgesia, and draining pleural effusion are some of the definitive measures.
- Intubation and mechanical ventilation may be used in severe cases.

Type of Acid-Base Disorder	<i>Defect</i>	<i>Common Causes</i>	<i>Compensation</i>
Respiratory acidosis	Retention of CO ₂ (Decreased alveolar ventilation)	Respiratory center depression: morphine, CNS injury, Pulmonary disease: emphysema, pneumonia	<u>Renal</u> Retention of bicarbonate, excretion of acid salts, increased ammonia formation Chloride shift into red cells
Respiratory alkalosis	Excessive loss of CO ₂ (increased alveolar ventilation)	Hyperventilation: Emotional Severe pain Assisted ventilation Encephalitis	<u>Renal</u> Excretion of bicarbonate, decreased excretion of acid salts decreased ammonia formation

Metabolic acidosis	Retention of fixed acids or Loss of base bicarbonate	Diabetes, Azotemia, Lactic acid accumulation, Starvation. Diarrhea, Small-bowel fistula	<u>Pulmonary</u> (rapid) Increased rate and depth of breathing Renal (slow) As in respiratory acidosis
Metabolic alkalosis	Loss of fixed acids Gain of base bicarbonate Potassium depletion	Vomiting Gastric suction (pyloric obstruction) Excessive bicarbonate intake Diuretics	<u>Pulmonary</u> (rapid) Decrease rate and depth of breathing Renal (slow) As in respiratory alkalosis