L16: Electrolytes Imbalance (H_2O/Na^+)

Medicine433@yahoo.com

MED 433

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MEDICINE 433

objectives

1. Recognize the systems that control body sodium and water contents.
2. Understand the difference between body volume status and serum Sodium concentration.
3. Recognize the different types of intravenous fluids used at bedside.
4. Know the workup for Hyponatremia.
5. Know how to calculate the water deficit in Hypernatremia.

Color index: Step up to medicine , slide , Doctor's note , Davidson , Extra Explanation

Definitions:

- **Osmosis:** movement of water. (from low osmotic area to high osmotic area).
- **Diffusion:** movement of solutes .
- Filtration: movement of both solutes and water.
- **Osmolality:**

- Osmoles in solution: mOsm/kg water
- Calculate plasma osmolality (Posm) = (2 x serum Na+) + blood urea + glucose
- For Na+, K+ and Cl: 1 mEq = 1 mOsm
- Normal osmolality of body fluids: 283-292 mOsm/kg water
- ECF and ICF are in ***osmotic equilibrium*** (**ICFosm = ECFosm = Posm)**
- Volume is more important than osmolality.

- **Tonicity :**

- To compare the osmolality of a solution to that of another solution (body fluid compartments)
- Used to compare the osmolality of intravenous solutions to that of the serum: ISOTONIC , HYPOTONIC and HYPERTONIC.

Sodium and Water

- *Intracellular K concentration* is *140* mEq/L.
- Extracellular (plasma and *interstitium*) Na concentration is 140 mEq/L.
- Osmolality determined by : (2 x serum Na+) + blood urea + glucose

○ Sodium homeostasis:

1. Sodium is actively pumped out of cells and is therefore restricted to the extracellular space. It is the main osmotically active cation of the ECF.

2. An increase in sodium intake results in an increase in ECF volume, which results in an increase in GFR and sodium excretion. A decline in the extracellular circulating volume results in a decreased GFR and a reduction in sodium excretion.

3. Diuretics inhibit Na+ reabsorption through various mechanisms in the renal tubular system. Furosemide and other loop diuretics inhibit the Na+ –K+ –Cl– transporter in the thick ascending limb of the loop of Henle, whereas thiazide diuretics inhibit the Na+ –Cl- cotransporter at the early distal tubule. However, the majority of Na+ reabsorption occurs in the proximal tubule.

4. A decrease in renal perfusion pressure results in activation of the renin-angiotensinaldosterone system. Aldosterone increases sodium reabsorption and potassium secretion from the late distal tubules.

Sodium and Water

○ Water homeostasis:

1. Osmoreceptors in the hypothalamus are stimulated by plasma hypertonicity (usually >295 mOsm/kg); activation of these stimulators produces thirst.

2. Hypertonic plasma also stimulates the secretion of antidiuretic hormone (ADH) from the posterior pituitary gland. When ADH binds to V2 receptors in the renal collecting ducts, water channels are synthesized and more water is reabsorbed.

3. ADH is suppressed as plasma tonicity decreases.

4. Ultimately, the amount of water intake and output (including renal, GI, and insensible losses from the skin and the respiratory tract) must be equivalent over time to preserve a steady state.

5. When a steady state is not achieved, hyponatremia or hypernatremia usually occurs.

ECF volume= **absolute** amounts of Sodium and water
Plasma Na+ = **ratio** between the amounts of Sodium and water (Concentration)

Normal body fluid compartments

Fluid compartments are separated by thin semi-permeable membranes with pores to allow fluid movement and molecules of a specific size to pass while preventing larger heavier molecules from passing.

- Total body water (TBW): **(0.6 x Body Weight)**
- Men = 60% of body weight.
- Women= 50% of body weight.
- newborn infant= 70% of body weight.
- Elderly= 50% of body weight. (Percentage of TBW decreases with age and increasing obesity).
- Distribution of water:

a. Intracellular fluid (ICF) is two-thirds of TBW (or 40% of body weight)—The largest proportion of TBW is in skeletal muscle mass.

b. Extracellular fluid (ECF) is one-third of TBW (or 20% of body weight).

- Interstitial fluid (ISF) is 3/4 ECF (**0.75 x ECF**).
- Plasma is 1/4 ECF (**0.25 x ECF).**
- Normal water intake is 1-1.5 L/day.
- Normal output:
- Total urine output is 1-1.5 L/d (the normal range).
- Insensible water loss*: Stool, breath, sweat= 800 ml/d (Increases by 100-150 ml/d for each degree above 37 C).

For body fluid compartments remember the (60–40-20 rule).
- TBW is 60% of body weight (50% for women).
- ICF is 40% of body weight.
- ECF is 20% of body weight (interstitial fluid 15% and plasma 5%).

Remember : Fluid shift depends on **hydrostatic and oncotic** pressures.

* Insensible water loss = Water loss via evaporation from the skin and respiration. This is highly **variable** , increases with fever, sweating, hyperventilation, and tracheostomies (unhumidified air)

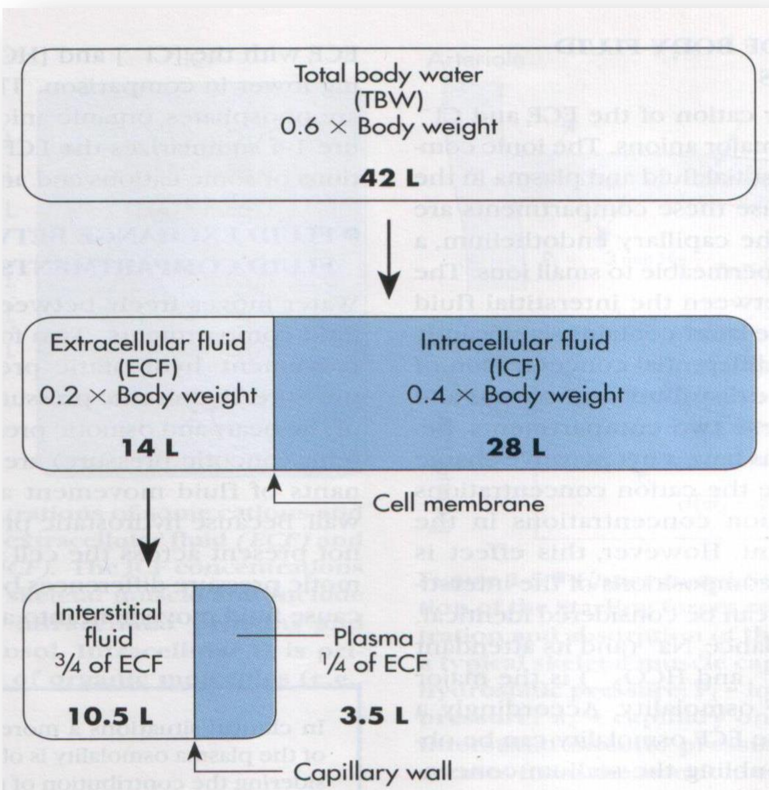
Total Body Water
TBW
(0.6 x Body Weight)

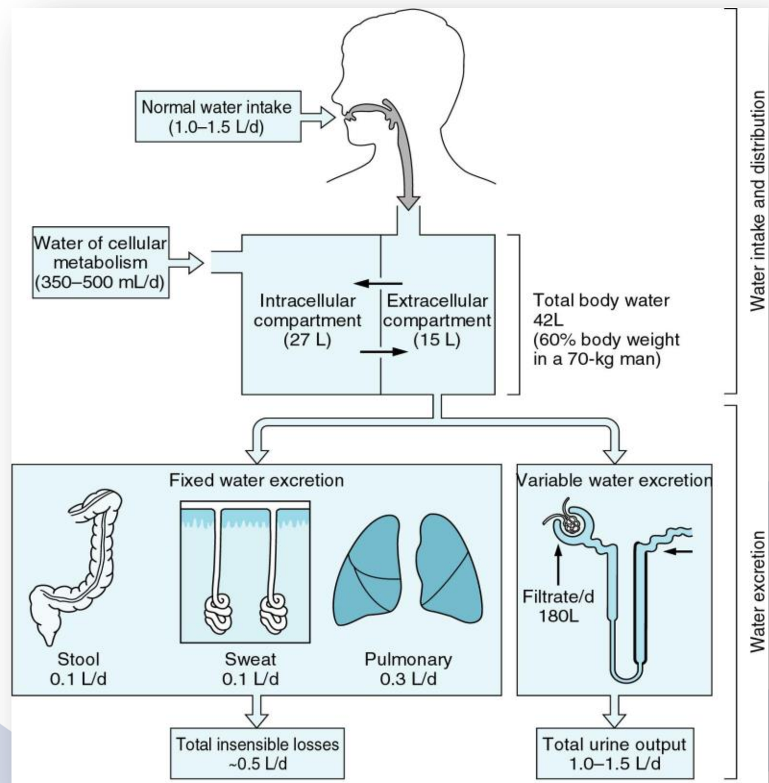
Intracellular Fluid (ICF)
(2/3 x TBW)
(0.4 x Body weight)

Extracellular Fluid (ECF)
(1/3 x TBW)
(0.2 x Body weight)

Interstitial Fluid (ISF)
(3/4 x ECF)
(0.75 x ECF)

Plasma (IV)
(1/4 x ECF)
(0.25 x ECF)





> Volume is more important than osmolality in controlling ADH secretion e.g. (if there is low blood volume ADH will be secreted even if there is low osmolality). E.g : in heart failure although there is low Na the ADH still being secreted because there is low effective arterial blood volume

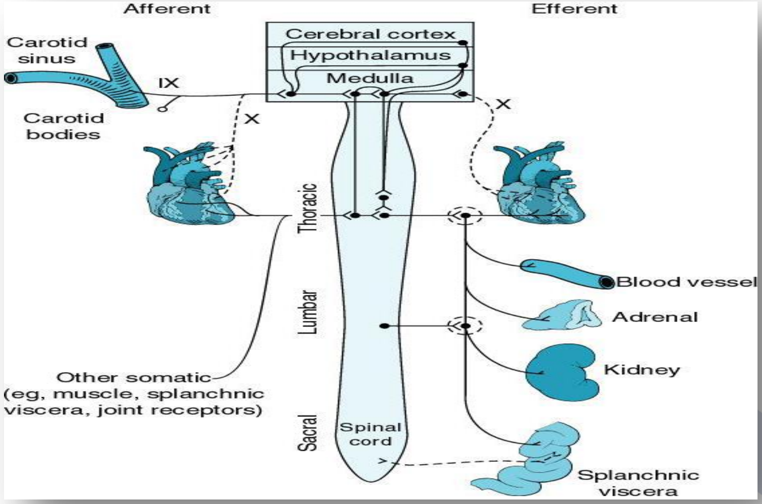
○ Regulation Mechanisms of Fluid and Electrolytes:

- Regulation of osmolality and volume is achieved through **thirst** and the **osmoreceptor-antidiuretic hormone system (vasopressin).**
- The regulation of volume also occurs through neurological and renal mechanisms:

- The stretch receptors (baroreceptors)
- The Renin-Angiotension-Aldosterone System
- The Natriuretic peptides

○ **Afferent limb sensors of extracellular fluid volume:**

- **Cardiopulmonary** (venous circulation), Atria ,Ventricular and pulmonary.
- **Arterial:**
  - Extrarenal: aortic arch, carotid sinus
  - Intrarenal: juxtaglomerular apparatus
- **Others:** Central nervous system and Hepatic.



- Controlled by autonomic NS.
- Receptors exist on Afferent pathway ,e.g.Aortic Arch& heart & other organs.
- Efferent controls Cardiac output, Renin system, And Kidney absorption.

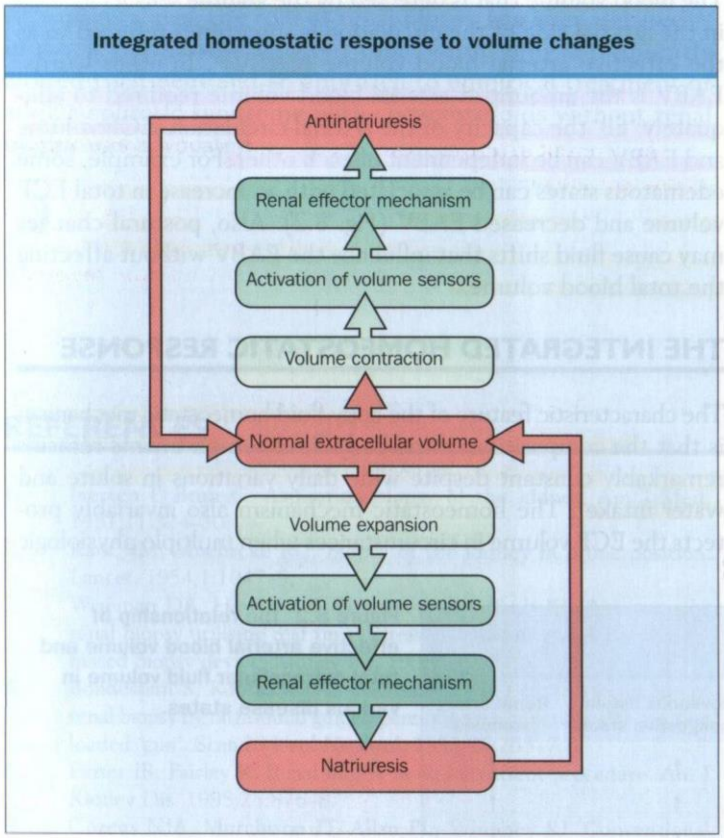
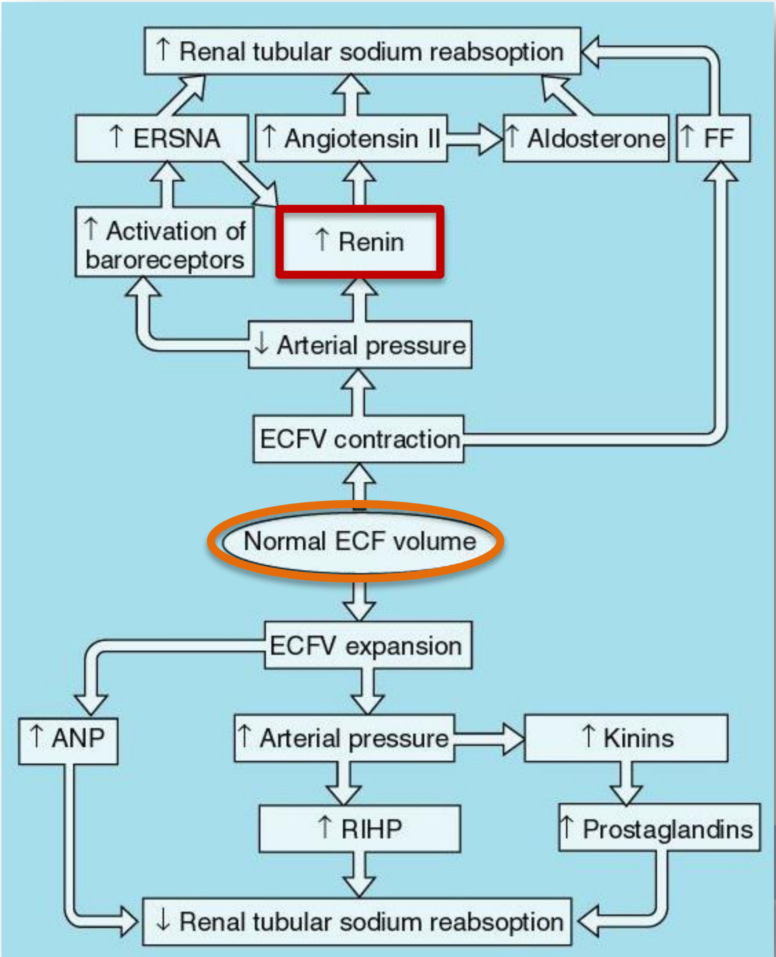
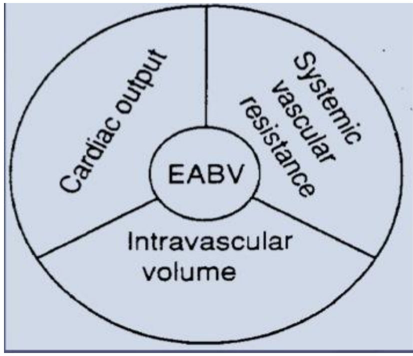


Figure 8.3 A general overview of the integrated homeostatic response system regulating extracellular fluid volume during volume contraction and expansion.





○ Effective Arterial Blood Volume (EABV):

EABV is the amount of arterial blood volume required to adequately '<u>fill</u>' the capacity of the arterial circulation, determined by <u>cardiac output</u> and <u>systemic vascular resistance</u>.

↓ EABV	EABV↑
↑CO ↑SVR ↑Renal Na retention	↓CO ↓SVR ↓Renal Na retention

○ ECF volume and EABV can be <u>independent</u> of each other:

- **Edematous states**: increase in total ECF volume and decreased EABV
- **Postural changes** may cause shifts that influence the EABV without affecting the total blood volume

The cause of has low effective arterial blood volume or EABV might be heart failure, liver cirrhosis or chronic kidney disease.

- EABV differs from intravenous depletion because in intravenous depletion there is loss of volume (fluid) but in EABV the fluid is accumulated in the veins.
- To know if the Patient has low effective arterial blood volume or EABV he will have hypervolemia (edema) with low blood pressure.
- In case of EABV, Low blood pressure would activate RAAS and ADH secretion causing more Na and fluid retention.
- In case you have a patient with low EABV try to increase the contractility of heart.

○ Assessing volume status:

- Tracking input and output is not an exact science either because there is no accurate way of calculating insensible losses.
- Monitoring urine output is very important in the assessment of volume status: **Normal urine output in infants is more than 1.0 mL/kg/hour, while normal urine output for an adult is generally regarded as 0.5 to 1.0 mL/kg/hour.** Low urine output could be a sign of volume depletion.
- Daily weights may give a more accurate assessment of volume trends.

- **Keep in mind** the larger picture of the patient's condition:
  a. In general, patients with **sepsis, fever, burns, or open wounds** have high insensible losses (and higher metabolic demands).
  b. For each degree of atmospheric temperature over 37°C, the body's water loss increases by approximately 100 mL/day.
  c. Patients with **liver failure, nephrotic syndrome**, or any condition causing hypoalbuminemia tend to third-space fluid out of the vasculature and may be total-body **hypervolemic** but intravascularly depleted.
  d. Patients with **CHF** may have either **pulmonary edema** or **anasarca**, depending on which ventricle is involved.
  e. Patients with ESRD are very prone to hypervolemia for obvious reasons.

Basal Requirements :

Basal Water	Electrolytes	Carbohydrates
• 1st 10 kg: 4 ml/kg/h + • 2nd 10 kg: 2 ml/kg/h + • > 20 kg: 1 ml/kg/h	• Na: 50-150 mmol/d (NaCl) • Cl: 50-150 mmol/d (NaCl) • K: 20-60 mmol/d (KCl)	• Dextrose: 100-150 g/d (IV Dextrose minimizes protein catabolism and prevents ketoacidosis).

Calculation of Maintenance Fluids:

- **100/50/20 rule:**
  - 100 mL/kg for first 10 kg, 50 mL/kg for next 10 kg, 20 mL/kg for every 1 kg over 20
  - Divide total by 24 for hourly rate
  - For example, for a 70 kg man: 100 × 10 = 1,000; 50 × 10 = 500, 20 × 50 kg = 1,000. Total = 2,500. Divide by 24 hours: **104 mL/hour**
- **4/2/1 rule:**
  - 4 mL/kg for first 10 kg, 2 mL/kg for next 10 kg, 1 mL/kg for every 1 kg over 20
  - For example, for a 70 kg man: 4 × 10 = 40; 2 × 10 = 20; 1 × 50 = 50. Total = **110 mL/hour**

In case you want to give hypertonic solution infuse slowly (because if you infuse rapidly the fluids will shift from intracellular to extracellular and the cells will shrink and die)

Types of intravenous Solutions :

Crystalloids	**are intravenous solutions that contain solutes that readily cross the capillary membrane .** **- Dextrose and electrolyte solutions**
Colloids	are intravenous solutions that DO NOT readily cross the capillary membrane - Blood, albumin, plasma

Fluid replacement therapy:

1. **Normal saline (NS):** often used to increase **intravascular volume** if the patient is **dehydrated** or **has lost blood**; usually not the best option in patients with CHF unless the patient needs urgent resuscitation.
2. **D51/2NS** (5% dextrose in 1/2 NS).
   a. Often the standard maintenance fluid (often given with 20 mEq of KCl/L of fluid).
   b. Has some glucose, which can spare muscle breakdown, and has water for insensible losses.
3. **D5W** (5% dextrose in water).
   a. Used to dilute powdered medicines.
   b. May sometimes be indicated in correcting hypernatremia.
   c. Only one-twelfth remains intravascular because it diffuses into the TBW compartment, **so not effective in maintaining intravascular volume.**
4. **Lactated Ringer's solution** This is excellent for **replacement of intravascular volume**; it is not a maintenance fluid. It is the most common trauma resuscitation fluid. Do not use if hyperkalemia is a concern (contains potassium).

D5W: It's isotonic initially, but the glucose will be metabolized and the solution becomes hypotonic.

- D10W: for the patient with hypoglycemia. It's hypertonic initially, but, after a while it will become hypotonic because of glucose metabolism.

Hypovolaemia & Hypervolaemia

	Hyponatremia (Water Excess)	Hypernatremia (Water Deficit)
Hypovolemia (Sodium Deficit) Dehydration	Hemorrhagic Shock with good oral water intake	Diarrhea in Children and Seniors
Hypervolemia (Sodium Excess) Edema	Advanced Congestive Heart Failure	Hemodialysis Patient after 3% Saline infusion

- **Clinical features of Hypovolaemia & Hypervolaemia:**

	Hypovolemia	Hypervolemia
Symptoms	Thirst	Ankle swelling
	Dizziness on standing	Abdominal swelling
	Weakness	Breathlessness
Signs	Low JVP	Raised JVP
	Postural hypotension	Peripheral oedema
	Tachycardia	Pulmonary crepitations
	Dry mouth	Pleural effusion
	Reduced skin turgor	Ascites
	Reduced urine output	Hypertension (sometimes)
	Weight loss	Weight gain
	Confusion, stupor	

Hypovolaemia

Causes	1. GI losses due to vomiting, nasogastric suction, diarrhea, fistula drainage, etc. 2. Third-spacing due to ascites, effusions, bowel obstruction, crush injuries, burns 3. Inadequate intake 4. Polyuria—for example, diabetic ketoacidosis (DKA) 5. Sepsis, intra-abdominal and retroperitoneal inflammatory processes 6. Trauma, open wounds, sequestration of fluid into soft tissue injuries 7. Insensible losses—evaporatory losses through the skin (75%) and the respiratory tract (25%)
Diagnosis	1. **Monitor urine output and daily weights**. If the patient is critically ill and has cardiac or renal dysfunction, consider placing a Swan–Ganz catheter (to measure CVP and PCWP). 2. Elevated serum sodium, low urine sodium, and a BUN/Cr ratio of >20:1 suggest hypoperfusion to the kidneys, which usually (not always) represents hypovolemia. 3. Increased hematocrit: 3% increase for each liter of deficit 4. The concentration of formed elements in the blood (RBCs, WBCs, platelets, plasma proteins) increases with an ECF deficit and decreases with an ECF excess.
Treatment	1. **Correct volume deficit** a. Use bolus to achieve euvolemia. Begin with isotonic solution (lactated Ringer's or NS). b. Again, frequent monitoring of HR, BP, urine output, and weight is essential. c. Maintain urine output at 0.5 to 1 mL/kg/hour. d. Blood loss → Replace blood loss with crystalloid at a 3:1 ratio. 2. **Maintenance fluid** a. D51/2NS solution with 20 mEq KCl/L is the most common adult maintenance fluid. (Dextrose is added to inhibit muscle breakdown.)

You can check the urine output to know if the patient hypervolemic or hypovolemic. It takes time to know the osmolality of the urine but you can estimate by the specific gravity which can be obtained by dip stick.

Hypervolaemia

Causes	1. Iatrogenic* (parenteral overhydration) 2. Fluid-retaining states: CHF, nephrotic syndrome, cirrhosis, ESRD
Treatment	1. Fluid restriction 2. Judicious use of diuretics 3. Monitor urine output and daily weights, and consider Swan–Ganz catheter placement depending on the patient's condition.

* Iatrogenic= relating to illness caused by medical examination or treatment.

- Hyponatremia = Water Excess
- Hypernatremia = Water Deficit
- Hypervolemia = Sodium Excess "Edema"
- Hypovolemia = Sodium Deficit "Dehydration"

hypervolemia and hypovolemia are due to Na concentration problem. Examples:

- Hypervolemia (Sodium Excess)might be caused by hyperaldosteronism because aldosterone causes Na reabsorption and then fluid will follow causing hypervolemia.
- Hypovolemia (Sodium Deficit) like in case of diarrhea.

Hyponatremia

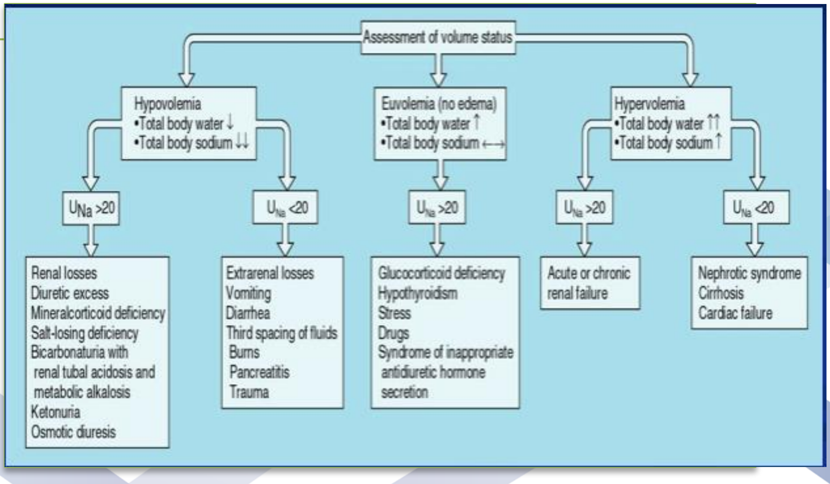
Normotonic or Isotonic Hyponatremia

- ***Factitious Hyponatremia***
- ***Pseudohyponatremia***
- **Results from laboratory artifact due to high concentrations of proteins or lipids**

Hypertonic Hyponatremia

- ***TranslocationalHyponatremia***
- **Resultsfromnon-Naosmolesinserum(often Glucose or mannitol) drawing Na-free H_2O from cells**
- **[Na+] declines by ~1.6 mEq/L for each 100 mg/dL [5.6 mmol/L] increase in serum glucose**

Hypotonic Hyponatremia

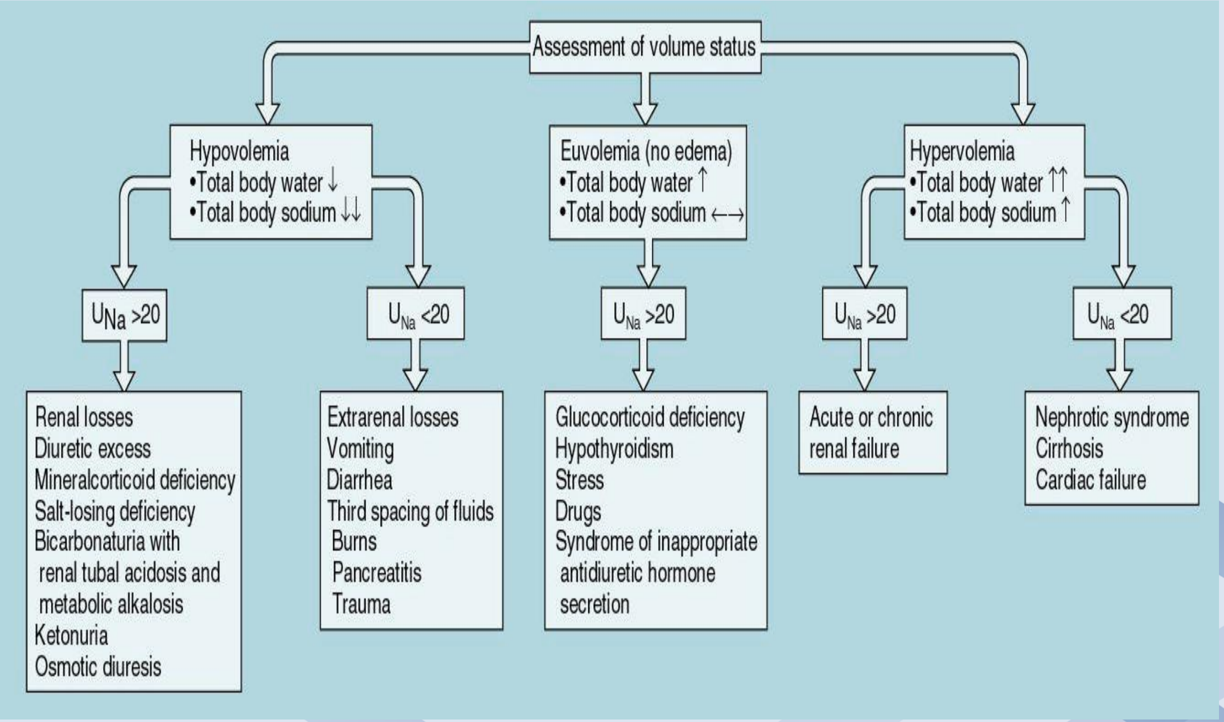


Hyponatremia

General characteristics

1. This refers to too much water in relation to sodium in the serum.
2. It is typically defined as a **plasma Na+ concentration** <135 mmol/L.
3. Symptoms usually begin when the Na+ level falls to <120 mEq/L. An important exception is increased intracranial pressure (ICP) (e.g., after head injury). As ECF osmolality decreases, water shifts into brain cells, further increasing ICP. (Therefore, it is critical to keep serum sodium normal or slightly high in such patients.)

Causes



Hyponatremia

In case of cholera: loss of Na and water so if the patient just drink water he may die because of hyponatremia. He has to take Na with water.

Classification of symptoms	All symptoms that can be signs of cerebral edema should be considered as severe or moderate symptoms.	
	○ Moderately severe - Nausea without vomiting - Confusion - Headache	○ Severe - Vomiting - Cardiorespiratory distress - Abnormal and deep somnolence - Seizures - Coma (Glasgow Coma Scale ≤8)
Diagnosis	1. Plasma osmolality—low in a patient with true hyponatremia 2. Urine osmolality a. Low if the kidneys are responding appropriately by diluting the urine—for example, primary polydipsia b. Elevated if there are increased levels of ADH—for example, SIADH, CHF, and hypothyroidism 3. Urine sodium concentration a. Urine Na+ should be low in the setting of hyponatremia. b. Urine Na+ concentration >20 mmol/L is consistent with a salt-wasting nephropathy or hypoaldosteronism. Diuretics may produce this as well. c. Urine Na+ concentration <40 mmol/L is consistent with (but does not define) SIADH.	
Treatment	1. Isotonic and hypertonic hyponatremias—Diagnose and treat the underlying disorder. 2. Hypotonic hyponatremia a. Mild (Na+ 120 to -130 mmol/L)—With hold free water, and allow the patient to re-equilibrate spontaneously. b. Moderate (Na+ 110 to 120 mmol/L)—loop diuretics (given with saline to prevent renal concentration of urine due to high ADH) c. Severe (Na+ < 110 mmol/L or if symptomatic)—Give hypertonic saline to increase serum sodium by 1 to 2 mEq/L/hour until symptoms improve. • Hypertonic saline rapidly increases the tonicity of ECF. • Do not increase sodium more than 8 mmol/L during the first 24 hours. An overly rapid increase in serum sodium concentration may produce central pontine demyelination.	

SIADH

- **Defined by** the hyponatremia and hypo-osmolality.
  - H: Hypoosmolar Hyponatremia (Posm <275 mOsm/Kg H2O)
  - I: Inappropriate urine concentration (Uosm >100 mOsm/Kg H2O)
  - V: Euvolemia, No diuretic use
  - E: Endocrine = normal Thyroid, adrenal and renal function
  - Hypouricemia (<238 mcmol/L) and low Urea (<3.5 mmol/L)

Diagnostic Criteria for SIADH:

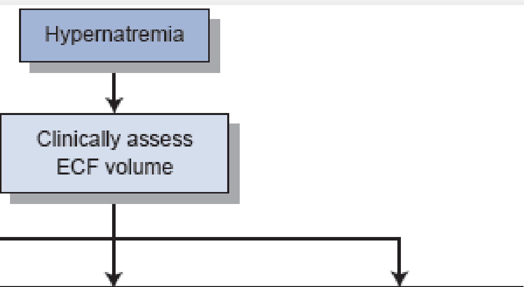
Essential criteria	Supplemental criteria
1.Effective serum osmolality <275 mOsm/kg 2.Urine osmolality >100 mOsm/kg 3.Clinical euvolemia 4.Urine sodium concentration >30 mmol/l with normal dietary salt and water intake 5.Absence of adrenal, thyroid, pituitary or renal insufficiency 6.No recent use of diuretic agents	1.Serum uric acid <0.24 mmol/l (<4 mg/dl) 2.Serum urea <3.6 mmol/l (<21.6 mg/dl) 3.Failure to correct hyponatremia after 0.9% saline infusion 4.Fractional sodium excretion >0.5% 5.Fractional urea excretion >55% 6.Fractional uric acid excretion >12% 7.Correction of hyponatremia through fluid restriction

SIADH: syndrome of inappropriate antidiuretic hormone is due to increase secretion of ADH. It is characterized by normal volume and hyponatremia (initially the ADH increases the volume then ANP will decrease the volume to normal by excreting Na which leads to hyponatremia)

Hypernatremia

- General characteristics

1. Defined as a plasma Na+ concentration >145 mmol/L
2. Refers to excess sodium in relation to water; can result from water loss or sodium infusion
3. Assess ECF volume clinically, as follows



Depleted	Normal	Expanded
Hypovolemic Hypernatremia	Isovolemic Hypernatremia	Hypervolemic Hypernatremia
Loss of Na^+ and water, but more water loss than Na^+ loss	Loss of water only Na^+ stores normal	Gain of Na^+ and water, but more Na^+ gain than water gain
Causes	Causes	Causes
• Renal loss • Diuretics • Osmotic diuresis (glycosuria) • Renal failure • Extrarenal loss • Diarrhea (GI losses) • Diaphoresis (skin losses) • Respiratory losses	• Diabetes insipidus • Insensible respiratory (tachypnea)	• Iatrogenic • $NaHCO_3$ therapy • TPN • Exogenous glucocorticoids • Cushing's syndrome • Saltwater drowning • Primary hyperaldosteronism

Hypernatremia

Clinical features	1. Neurologic symptoms predominate a. Altered mental status, restlessness, weakness, focal neurologic deficits b. Can lead to confusion, seizures, coma 2. Tissues and mucous membranes are dry; salivation decreases.
Diagnosis	1. Urine volume should be low if the kidneys are responding appropriately. 2. Urine osmolality should be >800 mOsm/kg. 3. Desmopressin should be given to differentiate nephrogenic from central diabetes insipidus if diabetes insipidus is suspected
Treatment	1. Hypovolemic hypernatremia—Give isotonic NaCl to restore hemodynamics. Correction of hypernatremia can wait until the patient is hemodynamically stable, then replace the free water deficit 2. Isovolemic hypernatremia—Patients with diabetes insipidus require vasopressin. Prescribe oral fluids, or if the patient cannot drink, give D5W. 3. Hypervolemic hypernatremia—Give diuretics (furosemide) and D5W to remove excess sodium. Dialyze patients with renal failure.

- **Water Deficit Calculation:**
  - Current Total Body Water = 0.6 x Current Body Weight
  - Current TBW x Current [Na+] = Target TBW x Target [Na+]
  - Target TBW – Current TBW = Water Deficit
  - Ongoing loss
  - IVF: type and rate
  - Reassessment

Hypernatremia and hyponatremia are due to water problem. Examples:

- Hypernatremia (Water Deficit) might be caused by dehydration or in case of diabetes insipidus (loss of fluid)
- Hyponatremia (Water Excess) might be caused by increase secretion of ADH e.g. SIADH (accumulation of fluid)

MCQs

Case1: A 63-year-old man alcoholic with a 50 pack-year history of smoking presents to ER with fatigue and confusion. Physical examination revels a blood pressure of 100/70 with no orthostatic change. Heart, lung and abdominal examination are normal and there is no pedal edema. Laboratory data are as following:

Test	Results	Normal value
Na	110 mEq/L	135 – 145 mEq/L
K	3.7 mEq/L	3.5 – 5.0 mEq/L
Cl	82 mEq/L	98 – 106 mEq/L
Hco3	20 mEq/L	100 – 140 mEqL
Glucose	100 mg/dl	59 – 105 mg/dL
BUN	5 mg/dl	7 – 22.4 mg/dL
Creatinine	0.7 mg/dl	0.8 – 1.4 mg/dL (male)0.56 – 1.0 (female)
Urinalysis	Normal	Normal
Specific gravity	1.016	1.003 – 1.030

1. Which one is the most likely diagnosis?

a. Volume depression

b. Inappropriate secretion of Antidiuretic hormone.

c. Psychogenic polydipsia

d. Cirrhosis

e. Congestive heart failure

Case 2: A 39-year-old woman is admitted to the gynecology service for hystroctomy for symptomatic uterine fibroids. Postoperatively the patient develops an ileus accompanied by severe nausea and vomiting; odanserton (anti-emetic) is piggybacked into IV of D5 1/2 NS (Dextrose 5% **in** 0.45% Normal Saline) running at 125 cc/h. On the second postoperative day the patient becomes drowsy and displays a few myoclonic jerks. Lab investigations are shown below (urine studies for Na and osmolity are sent to the lab.

Test	Results	Normal value
Na	118mEq/L	135 – 145 mEq/L
K	3.2 mEq/L	3.5 – 5.0 mEq/L
Cl	88 mEq/L	98 – 106 mEq/L
Hco3	22 mEq/L	100 – 140 mEqL
BUN	3 mg/dl	7 – 22.4 mg/dL
Creatinine	0.9 mg/dl	0.8 – 1.4 mg/dL (male)0.56 – 1.0 (female)

2. Which one is the most appropriate next step?

a. Change IV fluid to 0.9% (normal) saline and restrict free-water intake to 600 cc/d.

b. Change Odansteron to promethazine, change IV fluid to lactated Ringer solution, and recheck the NA in 4 hours.

a. Start 3% (hypertonic) saline, make the patient, make the patient NPO (nothing per mouth), and transfer the patient to ICU.

a. Change the IV fluid to normal saline and give fursemide 40 mg IV stat.

b. Make the patient NPO and send for stat CT scan of the head to look for cerebral edema

MCQs

Case 3: A-27-year old pedestrian is brought to the emergency by ambulance following an accident in which he was struck by a moving car. Among other injuries he is found to have a large laceration over the occipital area of his head. He is stabilized, given adequate lactated Ringer's solution and blood transfusion due to acute blood loss, and taken to ICU. Two days later he is lethargic and has a serum sodium level of 188 mEq/L.

3. What is this patient's expected plasma osmolality, urine osmolality, and clinical volume status??

Choice	Plasma	Urine	Clinical status
A	Hypotonic	Hypertonic	Euvolemic
B	Hypotonic	Hypertonic	Hypervolemic
C	Isotonic	Hypertonic	Hypovolemic
D	Hypertonic	Hypotonic	Hypovolemic
E	Hypertonic	Hypotonic	Euvolemic

Case 4: A 65-yearold patient with a history of bipolar disorder, well-controlled with lithium is being evaluated for hypernatremia. Her only complaint is 4 months of polyuria and thirst. Her blood pressure is 102 106/68 mmHg and puse is 102/min. Physical examination is unremarkable. Laboratory tests show:

Test	Results	Normal value
Na	147 mEq/L	135 – 145 mEq/L
K	4.7 mEq/L	3.5 – 5.0 mEq/L
Cl	110 mEq/L	98 – 106 mEq/L
Hco3	24 mEq/L	100 – 140 mEqL
BUN	12 mg/dl	7 – 22.4 mg/dL
Creatinine	1.1 mg/dl	0.8 – 1.4 mg/dL (male)0.56 – 1.0 (female)
Plasma osmolality	305 mOsm/kg	
Urine osmolality	200 mOsm/kg	

4. Which of the following is most likely to resolve the patient's electrolyte imbalance?

a. Exogenous ADH
b. Fluid restriction
c. Intravenous fluids
d. Potassium restriction
e. Thiazide diuretic

Answers : 1-B 2-C 3-A 4-E

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DONE BY

Faroq Abdulfattah	Raneem AlOtaibi
Khalid Alsuhaibani	Aisha AlRaddadi
Ahmed Alhussien	Awatif Alenazi

Medicine is a science of uncertainty and an art of probability

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