Electrolyte imbalance (Sodium & Water)

Objectives:

- Recognize the systems that control body sodium and water contents.
- Differentiate between total body sodium content (volumestatus) and serum sodium concentration (Hypo-and Hypernatremia).
- Use the different types of IV fluids in clinical practice.
- Calculate the water deficit in Hypernatremia.
- Explain the workup of Hyponatremia.

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Resources: 435 team + Davidson + Kumar + Master the board + Dr's handout.

- Editing file
- Feedback

Please note,

since this lecture has no slides to follow, we took from multiple books (according to the objectives) and add them all together along with doctor's handout (all are written in black)

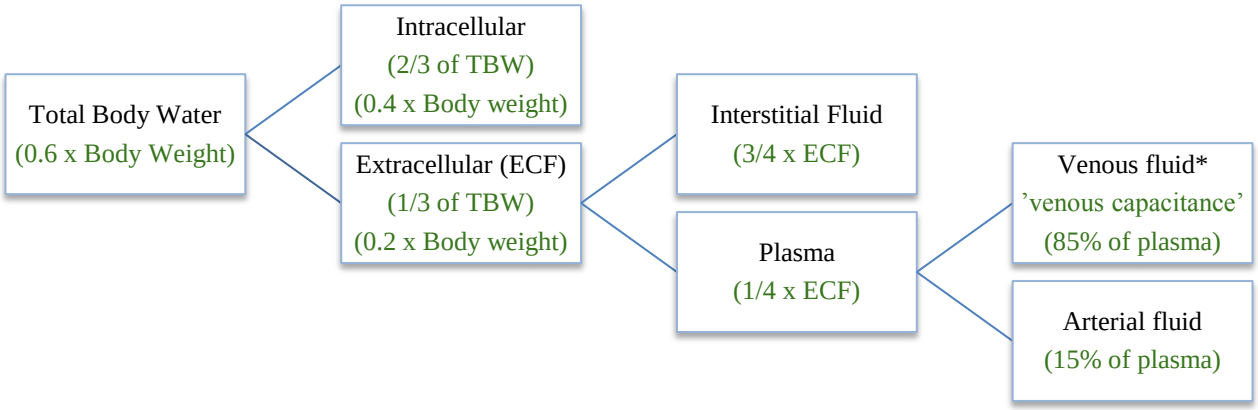
Basic Information

★ Total Body Water:

Percentage of TBW decreases with age and increasing obesity (TBW decreases because fat contains very little water):

- Men: Total body water (TBW) = 60% of body weight. In a 70 kg 30 y/o man TBW will be 42 L in which 28 L will be intracellular and 14 L extracellular (10.5 L in the interstitium and 3.5 plasma)
- Women: TBW = 50% of body weight. Females have proportionately more body fat than males.

★ Distribution of water:



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%).

o Electrolytes are substances dissolved in solutions and dissociated into particles called ions
1. Cations: Positively charged ions
2. Anions: Negatively charged ions

o Definitions:
- Osmosis: movement of water
- Diffusion: movement of solutes
- Filtration: movement of both solutes and water

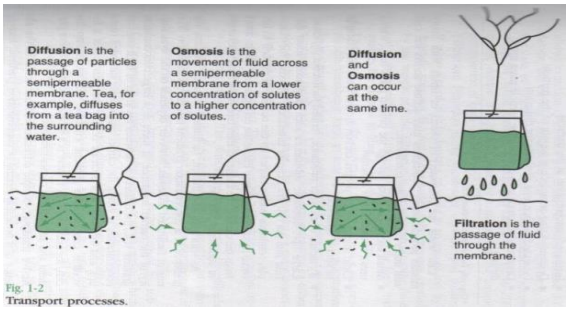


Fig. 1-2
Transport processes.

★ Composition of the fluid compartments:

→ Electrolytes concentration (mmol/L):

	Plasma	Interstitial fluid	Intercellular fluid
Na	142	144	10
K	4	4	160

- The dominant cation in the ICF is potassium, while in the ECF it is sodium:
  - The major force maintaining the difference in cation concentration between the ICF and ECF is the sodium–potassium pump.
- An important difference between the plasma and interstitial ECF is that only plasma contains significant concentrations of protein:
  - The difference in protein content between the plasma and the interstitial fluid compartment is maintained by the protein permeability barrier at the capillary wall (permeability will increase in pathological cases "Capillary leak syndrome" in sepsis and septic shock). This protein concentration gradient contributes to the balance of forces across the capillary wall that favour fluid retention within the capillaries (the colloid osmotic, or oncotic, pressure of the plasma البروتين يحافظ على الإنكوتيك بريشر داخل اوعية الدم والإنكوتيك دايما اناني ياخذ السوائل من برى ويدخلها عنده), maintaining circulating plasma volume.
- What is the Starling forces?

Hydrostatic + oncotic pressure, forces across the capillary wall

الهايدروستاتيك بريشر دائما معطاء يعني ياخذ السوائل الي عنده ويطلعها لبرى

فالتغير في هذي القوى يحدد Whether fluid will move out of the blood into the interstitial fluid or in the opposite direction.

- Starling forces will dictate fluid movement to the interstitial compartment to "bathe" the cells with nutrition and oxygen.

Osmolarity vs Osmolality?

- **OsmolaLity Defined as=** the number of osmoles per kiLo of water (mOsm/kg water)
- **Normal osmolality of body fluids: 283-292** (mOsm/kg water) usually **measured**
- **OsmolaRity Defined as=** the number of osmoles per liteR of solution (mOsm/L for example Plasma) usually **calculated**
- The plasma osmolarity can be calculated from the plasma concentrations of sodium, urea and glucose, as follows:

Calculated plasma osmolarity = (2 x serum $[Na^+]$) + blood urea + glucose

The factor of 2 applied to sodium concentration allows for associated anions (mainly chloride and bicarbonate).

Notice: here Na between brackets$[Na^+]$ which means sodium CONCENTRATION, Remember concentration means that it depends on two things: (water and sodium)
plasma osmolarity mainly depends on the concentration of sodium

Blood urea Do Not contribute to effective osmolarity because it moves easily across cellular membrane therefore it's ignored in calculation even with AKI. BUT The only situation we include blood urea in calculation when we do acute dialysis for uremic patient because urea across BBB much slower than the remover rate by dialysis "they have very high blood urea" so it might cause brain edema (Time dependent).

In normal situation (Glucose = 5.5 mmol) almost negligible. Unless if there's hyperglycemia

1. Hypotonic (ex. 100 mosm/L): Solutions have more water than solutes comparing to ECF
2. Isotonic (ex. 290 mosm/L): Solutions have the same solute concentration as the ECF
3. Hypertonic (ex. 400 mosm/L): Solutions have more solutes than water comparing to ECF

USMLE: To make the **conversion** from **mg/dl** to **mmol/L**

★ Tonicity vs Osmolarity?

Osmolarity describes the solution saturation. While tonicity compares the solution to other solution (Osmolarity of solution in comparison to the plasma) so when I say hypertonic it means that it has higher osmolarity than the reference point.

- In medicine, it Used to compare the osmolarity of intravenous solutions to that of the serum.
- Effect of osmotic pressure on the cells:
    - To equilibrate osmotic pressures: water tends to move from solution of low osmolarity to solution of high osmolarity concentration.
- Water movement between intracellular & extracellular space (Cell membrane) BASED on osmolarity (water move from low osmolarity to high osmolarity)
- What dictate water movement between intravascular & interstitial space (Endothelial cells)? Osmolality in addition to oncotic pressure + hydrostatic pressure (Starling forces).
- Most of the time urine is 500 mOsm/kg, it can be diluted (100 mOsm/kg) or concentrated (>800 mOsm/kg) depends on water balance (intake, output).
- When patient is in catabolic state the body will produce (about 400 mOsm/Day). So, for example if the urine osmolality at maximum is 1000 mOsm/L, he will need 1000 ml of fluids to return the osmolarity to the normal state.
- To sum up, we need 1:1 ratio to maintain balance between fluids and osmolarity.

★ Regulation Mechanisms of Fluid and Electrolytes:

★ Normal filtration/Day (GFR) ≈ 125 ml/Min = 180 to 200 L/Day, and only 2 Liters of them is excreted as a urine. 99.9% has to be reabsorbed.

Regulation of osmolality and volume is achieved through thirst and the osmoreceptor-antidiuretic hormone system (vasopressin):

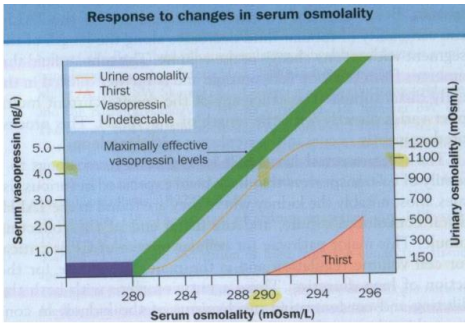
- ↑ plasma hypertonicity:
    1. Stimulation of Osmoreceptors in the hypothalamus → thirst
    2. Stimulate secretion of ADH → ADH increases water reabsorption.
- Volume is more important than osmolality in controlling ADH secretion e.g. (if there is low blood volume ADH will be secreted even if there 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 sensed by volume receptors.

The stretch receptors (baroreceptors)	The Renin-Angiotension-Aldosterone System:	The Natriuretic peptides:	Kinins & Prostaglandins
Mechanoreceptors located in the carotid sinus and in the aortic arch. Stimulus: Any change in blood pressure.	RAAS is the main dictate of volume in the body* decrease in renal perfusion results in activation of the RAAS system. Which enhances Aldosterone releases → increases Na reabsorption from the Distal ducts.	Produced by heart atrium in response to an increase in blood volume lead to increase sodium excretion.	Vasodilator, Holds Na. "Have minor role"

- ADH shares the regulation in BOTH Na balance & water balance.

- In Ramadan → No fluid intake → decrease in volume of urine and it will be concentrated → so we feel dizzy due to minor hypoglycemia + hyperosmolarity. We call it Conservational state.

- When you are thirsty that means that your urine is maximally concentrated and ADH can't control this much of concentration.



As soon as the plasma osmolality reaches 280 mOsm/kg the secretion of ADH increases to preserve water. With that urine starts to become concentrated meaning urine osmolality will increase up to 1200 mOsm/kg but reaches a platau when plasma osmolality reaches 290 mOsm/kg and thrist then kicks in which is stimulated by osmoreceptors.

Normal Plasma Osmolality: 280 – 290 mOsm/kg

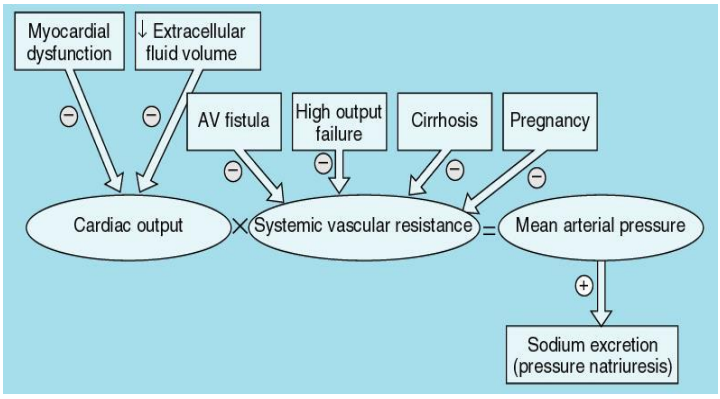
Normal urine Osmolality: 100 – 800 mOsm/kg "in practice"

★ Effective Arterial Blood Volume (EABV):

- **What is EABV:** (it is a concept the fullness of the arterial vascular compartment) is the amount of arterial blood volume required to adequately 'fill' the capacity of the arterial circulation.
- The fullness of the arterial compartment depends on a normal ratio between cardiac output and peripheral arterial resistance. Thus, diminished EABV is initiated by a fall in cardiac output or a fall in peripheral arterial resistance. When the EABV is expanded, this in turn leads to an increase in urinary sodium excretion and vice versa, To sum up:

(EABV has 3 components: Cardiac output, Systemic vascular resistance & intravascular volume)

BP = CO x SVR
CO = HR x SV
SV = EDV – ESV



85% of the blood is in the venous side. So, you can have a patient effectively with hypovolemic but totally hypervolemic

Effectively = in arterial side
Totally = arterial + venous

↓ EABV leads to: كتعويض اذا قل الدم داخل الفيزل وش بيصير:	↑ EABV leads to :
• ↑CO • ↑Systemic vascular resistance • ↑renal Na retention = ↑ volume	• ↓ CO • ↓ Systemic vascular resistance • ↓ renal Na retention =↓ volume

- **ECF volume and EABV can be independent of each other:**
  - Edematous states: increase in total ECF volume and decreased EABV (eg: Heart failure, cirrhosis, nephrotic syndrome)

- Postural hypotension: may cause shifts that influence the EABV without affecting the total blood volume.مثلا لما اوقف الدم الي داخل الاوعيه بيتغير مكانه لكنه لم يزل داخل الوعاء

IV fluids

Before giving any type of I.V fluids you have to think of the type of solution, amount, rate and duration. You have to reassess the pt. to see if you continue with what you gave or not. etc.

★ Types of IV fluids:

1. **Hypotonic:** What happens after administration of IV? Water will move from ECF into ICF. E.g. Distilled Water, 0.45% NaCl (1/2NS), 0.33% NaCl (1/3NS).
2. **Isotonic:** What happens after administration of IV? It will remain in the ECF. E.g. NS (0.9% NaCl), Ringers Lactate, 2/3 DW-1/3 NS, 5% Dextrose in Water (D5W).
3. Hypertonic**:** What happens after administration of IV? Water will move from ICF to ECF. E.g. 3% NaCl , 10%-50% Dextrose , D5W-1/2 NS , D5NS , Amino acid solution. Recall: water always tend to move from area of low solutes concentration to area of high solutes concentration.

★ Intravenous Solutions (Crystalloids vs Colloids):

- **Crystalloids** are intravenous solutions that contain solutes that readily cross the capillary membrane (contents: water + small electrolytes). Examples: Dextrose and electrolyte solutions

- **Colloids** are intravenous solutions that DO NOT readily cross the capillary membrane (contents: water + protein). Examples: Blood, albumin, plasma. Are large molecules that have an osmotic effect.
- If u need volume expander[1] u must use colloid or isotonic saline bc u don't want fluid goes inside the cell at this point, u need to maintain the perfusion of tissue which comes from raising BP. U may get case in the exam with severe hypotension asking to choose the appropriate IV? albumin or NS.
- Can u give free water IV? NO bc free water cause cell lysis & thrombophlebitis (if given in peripheral line).
- All cells use ketones except RBCs, Why? Bc No mitochondria.
- General rule: 1 L water = 1Kg …. 1 L plasma ≠ 1 Kg

[1] Volume expander fluid: tend to stay within the vascular space and increase intravascular pressure

★ The Differences between each Intravenous Solutions:

Solution	Components	OsmolaRity (mosm/L)	indication	Distribution (normal person) (no need to memorize)
D5W	Glucose = 5 (g/100 mL) Or 50 (g/L) It composed of 5% dextrose & water	253 Isotonic initially, but after a while the glucose will be metabolized and driven intracellularly by insulin and the solution becomes hypotonic.	- As maintenance fluid, the amount of glucose here is sufficient to prevent ketogenesis and Hypoglycemia but not nutritional. - Can be used for pt who has hypernatremia and need free water intake through IV. - NOT used for resuscitation.	If u take 1 Liter of D5W (80 ml will stay IV, 250 ml will shift to ISF & 670 ml will go inside the cell). NOT volume expander fluid bc small amount stay iv.
Normal saline (NS) (0.9% NS)	Na=154 (mEq /L) Cl =154 (mEq /L)	308 154 Na+154 Cl =308 omsolarilty Isotonic	Mainly **resuscitation** fluid (ex: if someone is hypovolemic u need to support blood pressure volume u should give saline) - Also given after surgery. - Can be given in a bolus.	If u take 1 Liter of NS (250 ml will stay IV and 750 ml will shift to ISF) NS is isotonic so why it will shift to another compartment? Bc the hydrostatic pressure goes up & ↓ oncotic. - When saline go to interstitial, what will happen to the pt? Pitting EDEMA. If u keep pushing NS what will happen to Cl in plasma? Cl will go up while bicarbonate will pushed out → dilutional acidosis.
Half saline (½ NS) (0.45% NS)	Na=77 (mEq /L) Cl =77 (mEq /L) A liter of half saline = half Liter of saline & half Liter of water	154 Hypotonic 77 Na + 77 Cl = 154 omsolarilty	maintenance fluid (when someone is eating a little bit, not worry about hypoglycemia, 1\2 NS is enough) - Intracellular dehydration. Hypovolemic hyponatremic pt (Cholera) - NOT used for resuscitation	If u take 1 Liter of ½ NS (165 ml will stay IV, 500 ml will shift n ISF & 335 ml will Go inside the cell) so ½ NS can be used when someone has intracellular dehydration, but can NOT be used when someone hypotensive 'not resuscitation Bc only 165 stay intravenously which not support blood pressure. That's why ½ NS used as a maintenance not for replacing ACUTE volume loss
D5 NS	Glucose =5 (g/100 mL) Na=154(mEq /L) Cl=154(mEq /L)	561 initially hypertonic but eventually after glucose burned = 308 - D5W alone is isotonic but adding NS to it makes it hypertonic	- Can be used as slow infusion for someone who needs some volume and fasting.	Same as NS (see above)
D5 ½ NS	Glucose = 5 (g/100 mL) Na=77 (mEq /L) Cl =77 (mEq /L)	407 initially hypertonic but eventually after glucose burned = 154 - D5W alone is isotonic but adding ½ NS to it makes it	Before surgery (Any time pt fasting as maintenance fluid who is NOT hypovolemic) NOT given as bolus	Same as ½ NS (see above)

		hypertonic.		
2/3 D5W + 1/3 NS	Glucose =33 (g/L) Na=50(mEq /L) Cl =50(mEq /L)	285 initially isotonic eventually hypotonic	Same as D5 ½ NS	
Ringer's Lactate	Na= 130(mEq /L) K=4 (mEq /L) Ca=3 (mEq /L) Cl=109 (mEq /L) Lactate=28 (g /L)	274 isotonic	Used for maintenance. (Can be resuscitation fluid) - Rapid infusion will lead to increase lactic acid. - Surgeons love to use it. - Almost identical to plasma.	NOTE: More physiological "balanced" but **BE CAUTION with (AKI & sepsis)** - Bc it has k (4 mmol\L) if someone get 4 L of ringer lactate he will develop hyperkalemia. - if someone has septic shock "his liver Is shocked" & has acidemia if I give lactate it will accumulate in liver and make acidemia worse.

★ Basal Requirements:

Basal Water	**Calculation of Maintenance Fluids:** **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 70kg man: (4 × 10 = 40) + (2 × 10 = 20) + (1 × 50 = 50) Total = **110 mL/hour.**
Insensible water loss	- Stool, breath, sweat: 800 ml/d - Increases by 100-150 ml/d for each degree above 37.
Electrolytes	- Na:1 meq/kg/day=1 mmol/kg/day =1 mOsm /kg/day - Cl: 1 meq/kg/day - K: 1 meq/kg/day
Carbohydrates	- Dextrose: 100-150 g/d - IV Dextrose minimizes protein catabolism and prevents starvation ketoacidosis (enough for ketogenesis suppression not for nutritional use)

Total body sodium content (volume status) and serum sodium concentration (Water disorder)

★ Sodium and Water:

- **ECF volume =** absolute amounts of Sodium and water.
- **Plasma sodium concentration =** ratio between the amounts of Sodium and water (Concentration).
- The best test to assess volume state is **urine lab test [Na]** **[Na+] = sodium concentration**

Sodium balance disorder	Water balance disorder
- Here we are talking about TOTAL Na in the body. - Disturbance of Na balance may lead to hypovolemia or hypervolemia. - The main determinant of volume is sodium content.	- Here we are talking about Na CONCENTRATION. - Disturbance of water balance may lead to hyponatremia or hypernatremia. - Water disorders: (causes a disturbance in Na concentration, not amount)
- ***Hypervolemia*** have = Sodium Excess ("Edema") (high volume = high sodium content)	- ***Hyponatremia*** have = Water Excess (Low sodium conc. = high water)
- ***Hypovolemia*** have = Sodium Deficit ("Dehydration") (low volume = Low sodium content)	- ***Hypernatremia*** have = Water Deficit (High sodium conc. = low water)

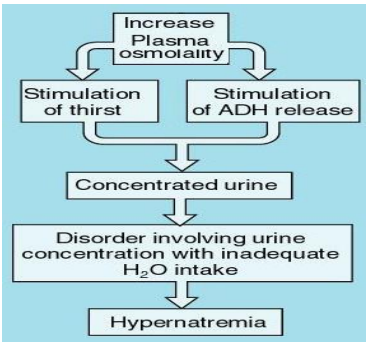
	Hyponatremia (Water Excess)	***Hypernatremia (Water Deficit)***
Hypovolemia (Dehydration) (Sodium Deficit)	Hemorrhagic Shock with good oral water intake	Diarrhea in Children and Seniors
Hypervolemia (Edema) (Sodium Excess)	Advanced Congestive Heart Failure	Hemodialysis Patient after 3% Saline infusion

Disorder in sodium Balance

★ Clinical features of Hypovolemia & Hypervolemia:

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

Disorder in water Balance



Hypernatremia: Water Deficit Calculation

General characteristic:

- Defined as a plasma Na+ concentration >145 mmol/L
- Hypernatraemia reflects less water in relation to sodium; affected patients may or may not have a concurrent abnormality in sodium balance.
- This is less common than hyponatraemia and nearly always indicates a water deficit.

Hypernatraemia is always associated with increased plasma osmolality, which is a potent stimulus to thirst. We don't check serum osmolality in every hypernatremic patient unless we suspect something else (ex: other osmoles intake like alcohol). Because hypernatremia is hypertonic by default = ↑Na, ↑osmolarity.
Not like hyponatremia which we have to check serum osmolality because we have: Isotonic, Hypertonic and hypotonic hyponatremia.

لما نتكلم عن الهايبر والهابو نتريما فإحنا نقصد **تركيز الصوديوم للماء** ,هل المحلول مركز بالصوديوم (هايبرنتريما) او الصوديوم الي فيه مخفف (هايبونتريميا) ,نروح لموضوعنا الهايبر نتريميا ونفكر بأسبابها , ياترى ايش الي خلى البلازما مركزه بالصوديوم؟

عشان نتخيل فل نفترض ان هذا الشكل يمثل النسبة الطبيعية في السيروم بين الصوديوم والماء

امم ممكن لان الصوديوم زاد والموية زادت لكن زيادة الصوديوم اكثر بكثير من المويه فصار البلازما مركز This called (hypervolemic hypernatremia)	او حتى ممكن ان كمية الصوديوم طبيعية لكن الموية قلت فصار البلازما مركز بالصوديوم This called (euvolemic hypernatremia)	او ممكن كلهم قلّوا لكن الموية قلت اكثر بكثيير من الصوديوم فصارت البلازما مركزة This called (hypovolemic hypernatremia)
		

★ Causes of hypernatremia:

- Hypernatraemia may occur in the presence of normal, reduced or expanded extracellular volume, and does not necessarily imply that total body sodium is increased.

Hypovolemia		Euvolemia (no edema)	Hypervolemia
• Total body water ↓↓ • Total body sodium ↓ (Na deficit with a relatively greater water deficit)		• Total body water ↓ • No change in Total body sodium (water deficit alone)	• Total body water ↑ • Total body sodium ↑↑ (Na retention with relatively less water retention)
Urinary Na > 20	Urinary Na < 20	Urinary Na variable	Urinary Na > 20

Due to renal losses:	**Due to Extrarenal losses:**	**Due to renal losses:**	**Extrarenal losses:**	**Sodium Gains:**
• Loop or osmotic Diuretic (It inhibits Na reabsorption & causes water loss) • Postobstructive diuresis (Copious amounts of salt and water are eliminated after the relief of a urinary tract obstruction) • Intrinsic renal disease (Renal tubular function is lost → ↓↓ reabsorption of water & Na)	• Burns • Diarrhea • Fistulas	• Diabetes insipidus (there's high volume water loss from insufficient ADH) • Hypodipsia (hypodipsia refers to a partial deficiency of the thirst mechanism → person unable to feel thirsty → ↓ water intake)	Insensible losses: (respiratory, dermal)	• Primary hyperaldosteronism (because aldosterone causes Na water retention) • Cushing's syndrome (because high Cortisol cause mineralocorticoid effect) • **Hypertonic dialysis** • Iatrogenic: (hypertonic Na HCO3, NaCl tablets)
★ **Treatment** ✓ **Correction of volume & water deficit:** 1- Pt is hypovolemic!! Administer isotonic saline till *hypovolemia* improves. 2- After that correct the *sodium level* by calculating water deficit accordingly Administer: (Half saline or D5W or oral water replacing the free water deficit & ongoing losses). ✓ **Treat causes of losses:** (Removal of diuretics, insulin…..)		★ **Treatment** ✓ **Correction of water deficit:** calculate water deficit accordingly Administer: (Half saline or D5W or oral water replacing the free water deficit & ongoing losses). ✓ **In central diabetes insipidus with severe loss:** give aqueous vasopressin (ADH)"pitressin" but monitor serum Na carefully to avoid water intoxication. ✓ **Long term therapy: in nephrogenic diabetes insipidus**: (the causes of nephrogenic diabetes insipidus r: lithium, chronic kidney disease, hypokalemia, hypercalcemia. they make ADH ineffective at kidney tubule) so u have to treat NDI according to the cause: (correct plasma Ca & K conc., give amiloride for lithium induced NDI, remove offending drug) ✓ **Long term therapy:** low Na diet		★ **Treatment** ✓ Remove Na. ✓ Discontinue offending agents. ✓ Administer furosemide. ✓ Provide hemodialysis as needed for renal failure.

★ Principles of Treatment:

- ✓ ↓ Volume → Saline.
- ✓ ↑ Volume (↑Na) → Loop diuretics. Or dialysis which much less common.
- ✓ Water deficit → Give free water (Oral or IV 'D5W or half saline')
- ✓ Water Excess → Water restriction + Diuretics.

★ Water Deficit Calculation: IMPORTANT !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

- **Water deficit**: (it is the amount of "water" required to lower the Plasma Na to 140 mmol/L)

Water Deficit = Target TBW – Current TBW

- Current Total Body Water = 0.6 x Current Body Weight
- Current TBW x Current [Na+] = Target TBW x Target [Na+]
- Target TBW = $\frac{\text{current TBW} \times \text{Current [Na]}}{\text{Target[Na]}}$

- كيف نحدّد التارقت صوديوم؟ حسب السؤال، كيف؟ إذا قال لنا (حتى يرجع للطبيعي) فخلاص 140.

لكن إذا حدّد مدة مثلًا قال خلال 24 ساعة؟ هنا عندنا رينج معيّن عشان نرجّع الصوديوم للطبيعي اللي هو من **8-6** إذا أكثر من كذا يصير خطر على المريض. فلو كان معدل الصوديوم عند المريض 159 وقال السؤال خلال يوم واحد هنا كم يصير التارقت؟ بالضبط! 151

Example: 60 kg man, sodium 165 mmol/L, What's water deficit to come back to normal:

Water Deficit= Target TBW – Current TBW

Target TBW= (36 x 165)÷140=42

Current TBW= 0.6 x60=36

Water Deficit = 42 – 36 = 6 Liter (need to give 6L water plus ongoing free water loses)

- Don't forget potential for ongoing loss either from diarrhea, diuresis or insensible loss.

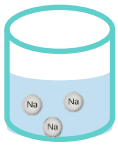
★ Clinical features:

- Patients with hypernatraemia generally have reduced cerebral function and cerebral dehydration. This triggers thirst and drinking, and if adequate water is obtained, is self-limiting. If adequate water is not obtained, dizziness, confusion, weakness and ultimately coma and death can result.

★ Hyponatremia:

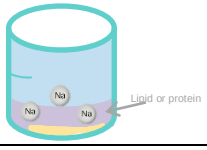
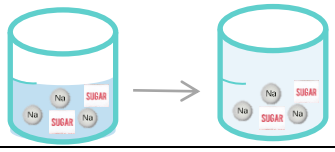
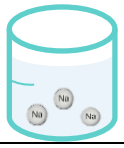
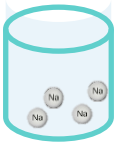
#General characteristic:

- This refers to too much water in relation to sodium in the serum.
- It is typically defined as a plasma Na+ concentration <135 mmol/L.



فل نفترض ان هذا الشكل
يمثل النسبة الطبيعية في
السيروم بين الصوديوم

#Causes and classification (based on serum osmolality):

Isotonic (Normotonic) hyponatremia (pseudohyponatremia) (Factitious) ما راح يجي عليها سؤال	**Hypertonic hyponatremia** (Translocational Hyponatremia) (dilutional hyponatremia) (true not pseudo)	**Hypotonic hyponatremia (True hyponatremia)** The causes depend on the associated changes in extracellular volume:		
		Hyponatraemia with hypovolaemia	**Hyponatraemia with Euvolaemia** (water retention alone)	**Hyponatraemia with hypervolaemia**
				
Increase in plasma solids lowers the plasma sodium **concentration.** But the **amount** of sodium in plasma is normal (hence, **pseudo**hyponatremia). الاجهزة لما تحسب تركيز الصوديوم تعتبر الليبد او البروتين من ماء البلازما فتكون الحسبة($\frac{Na}{water+lipid}$)فالنتيجة بلازما مخففة من الصوديوم مع إن عدد الصوديوم ما قل!! - Can be caused by any condition that leads to elevated protein or lipid levels. In cases such as: sever hyperlipidemia, Myeloma, Intravenous immunoglobulin (IVIG) infusion.	Results from ***none Na osmoles*** in serum **(often glucose or mannitol)** drawing free H2O from cells اذا زاد السوليوتس في السيروم اكثر من الي داخل الخلية هنا الموية بتروح كعادتها (من المكان الاقل تركيز بالسوليوتس الى المكان الاعلى تركيز بالسوليوتس) فتنتقل الى السيروم. بكذا السيروم صار فيه موية كثيرة فأصبح محلول مخفف من الصوديوم (هايبونتريما) مع إن عدد الصوديوم ما قل! [Na+ conc.] declines by ~2.4 mEq/L for each 100 mg/dL [5.5 mmol/L] increase in serum glucose. e.g: DM	See below	See below	See below

★ The causes of Hypotonic hyponatremia (True hyponatremia) Classified Based on The Volume State:

Hypovolemia		Euvolemia (no edema)	Hypervolemia (edema)	
• Total body water ↓ • Total body sodium ↓↓ (Na deficit with a relatively smaller water deficit)		• Total body water↑ • No change in Total body sodium (water retention alone, dilutional)	• Total body water ↑↑ • Total body sodium ↑ (Na retention with relatively greater water retention)	
Urinary Na >20	Urinary Na <20	Urinary Na >20	Urinary Na >20	Urinary Na <20

Due to renal losses: • Diuretic EXCESS (over time with excess use of diuretic, it will deplete the body of sodium & water) • Mineralocorticoid deficiency (because aldosterone causes Na retention) • **Osmotic diuresis** (lead to obligating electrolyte excretion): *Glucoseuria (causes water & electrolyte losses & thereby ECF volume depletion) *Bicarbonaturia (↑ bicarbonate excretion also obligate renal water & electrolyte loss) *Ketonuria (↑ ketoacid excretion also obligate electrolyte loss)	**Extrarenal losses:** • Diarrhea • Vomiting • Third spacing of fluids (occurs when too much fluid moves from the intravascular space into the interstitial or "third" space): *Burns *pancreatitis *Trauma All of these are also causes of hypernatremia; however, they cause hyponatremia if there is chronic replacement with free water. A little sodium and a lot of water are lost in urine, which is then replaced with free water that has no sodium. Over time, this process depletes the body of sodium and the serum sodium level drops.	• In the post-operative patient there is usually a short period of oliguria occurring as a physiological response to surgery. • Drug. • Syndrome of inappropriate ADH (↑ADH increases water reabsorption) • Hypothyroidism (hypothyroidism induces hyponatraemia by inappropriate release of ADH) • Polydipsia. • Beer potomania (is a specific hypo-osmolality syndrome related to massive consumption of beer)	Acute or chronic renal failure.	• Nephrotic syndrome (Sodium retention is primarily due to increased sodium reabsorption in the renal collecting tubules directly induced by the renal disease) • Cirrhosis (This is through a complex mechanism, but there is vasodilatation and hence underperfusion of the volume receptors → ↑ADH) • Cardiac Failure. (reduction in cardiac output and impaired perfusion of the volume receptors → ↑ADH)

★ Classification of Symptoms of Hyponatremia: IMPORTANT

- All symptoms that can be signs of cerebral edema should be considered as severe or moderate symptoms that can be caused by hyponatremia:

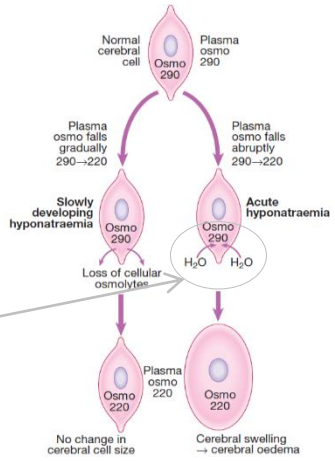
Moderately Severe	Severe
• Nausea without vomiting • Confusion • Headache	• Vomiting • Cardiorespiratory distress • Abnormal and deep somnolence نعاس • Seizures • Coma (Glasgow Coma Scale[2] ≤8) For **severe** hyponatremia, Need 3% hypertonic saline as emergency treatment

- For Moderately severe & **severe** hyponatremia, Need 3% hypertonic saline as emergency treatment.
- Symptoms of hyponatremia are dependent on how fast it occurs.
- Sodium means CNS symptoms, whether sodium level above the normal or below it.

[2] **Glasgow Coma Scale** is neurological used to describe the general level of consciousness

★ The effect of hyponatremia on the brain[3]:

Osmosis = Water moves from area of low conc. of solutes to area of high conc. of solutes
فهنا عندنا كمية قليلة من الصوديوم بالسيروم مقارنة بداخل الخليه و فالموية بتروح من برى الى داخل الخلية



#Water Excess:

Example: Current TBW 30, sodium 110 mmol/L, How much water excess he has?

Water Deficit= Current TBW - Target TBW

Target TBW= (30 x 110)÷140=23.6

Water Excess = 30 – 23.6 = 6.4 Liter

Summary

IV Fluids:

4. **Hypotonic:** Water will move from ECF into ICF. E.g. Distilled Water , 0.45% NaCl (1/2NS) , 0.33% NaCl (1/3NS)
5. **Isotonic:** It will remain in the ECF. E.g. NS (0.9% NaCl) , Ringers Lactate , 2/3 DW-1/3 NS , 5% Dextrose in Water (D5W)
6. **Hypertonic**: Water will move from ICF to ECF. E.g. 3% NaCl , 10%-50% Dextrose , D5W-1/2 NS , D5NS , Amino acid solution
7. **Crystalloids** are intravenous solutions that contain solutes that readily cross the capillary membrane (contents: water + electrolytes). Examples: Dextrose and electrolyte solutions
8. **Colloids** are intravenous solutions that DO NOT readily cross the capillary membrane (contents: water + protein). Examples: Blood, albumin, plasma.

Differentiate between total body sodium content (volume status) and serum sodium concentration (Hypo- and Hypernatremia)

Disorders in sodium balance: disturbances in balance affect the volume because sodium is the main

[3] symptoms of hyponatremia are dependent on how fast it occurs

volume determinant of volume		
	Hypervolemia	***Hypovolemia***
Signs	Swelling in ankles and abdomen, breathlessness	Thirst, weakness, dizziness on standing.
Symptoms	High JVP, Hypertension Weight gain Peripheral edema and pleural effusion	Low JVP, Postural hypotension Weight loss Reduced urine output and dry mouth

Disorders in water balance: disturbances in water are related to Na concentration, not Na amount.		
1- Hypernatremia: plasma Na+ concentration >145 mmol/L.		
Hypovolemia	**Euvolemia**	**Hypervolemia**
Total body water is decreased more than total body sodium.	Only total body water is decreased.	Total body sodium is increased more than total body water.

Disorders in water balance CONT: disturbances in water are related to Na concentration, not Na amount.		
2- *Hyponatremia*: plasma Na+ concentration <135 mmol/L		
Moderately Severe: Nausea without vomiting, Confusion, Headache	Severe Vomiting, Cardiorespiratory distress, Seizures Abnormal and deep somnolence, Coma (Glasgow Coma Scale[4] ≤8)	
A. Hypotonic hyponatremia		
A.1 Hyponatraemia with hypovolaemia	**A.2 Hyponatraemia with Euvolaemia**	**A.3 Hyponatraemia with hypervolaemia**
Na deficit with a relatively smaller water deficit	Increased Total body water only.	Na retention with relatively greater water retention
B. Hypertonic hyponatremia	**C. Isotonic hyponatremia**	
(Translocational Hyponatremia) (dilutional hyponatremia) (true not pseudo)	(pseudohyponatremia) (Factitious)	

[4] **Glasgow Coma Scale** is neurological used to describe the general level of consciousness

Questions

1- A 47 y/o male presented to the ER with 2 days history of diarrhea. His vitals BP=75/45, HR=113 , RR=23. How would you manage this patient?

A- Normal saline

B- Half normal saline

C- Quarter normal saline

D- 5% Dextrose

2- Which of the following is regulated by ADH ?

A- Sodium

B- Potassium

C- Water

D- Sodium & water

3- A 33 y/o male marathon runner presented to the ER with dizziness when standing and weakness. On examination, his JVP was low with reduced skin turgor . His HR = 132. Which of the following is the best initial treatment?

A- Administration of Hypertonic saline

B- Administration of Isotonic saline

C- Administration of Hypotonic saline

D- No intervention, only observe the patient.

4- A 27 y/o female patient presented to you with pain in her right forearm associated with redness, warmth of the skin and tissues after she had an IV fluid because of her hypovolemia. What is the most likely cause of her symptoms ?

A- Administration of Ringer's lactate

B- Administration of ½ Na

C- Administration of pure water

D- Administration of Na

5-The nurse evaluates which of the following patients to be at risk for developing Hypernatremia ?

A- 50 y/o with pneumonia, diaphoresis and high fever

B- 62 y/o with CHF taking loop diuretics

C- 39 y/o with vomiting and diarrhea

D- 60 y/o with lung cancer and SIADH

6- 83 y/o patient admitted with heart failure and a Sodium level of 113 mEq/L. He is behaving aggressively toward staff and does not recognize family members. When the family expresses concern about his behavior, the doctor would respond most appropriately by stating :

A- The patient may be suffering from dementia, and the hospitalization has worsened the confusion.

B- Most older adults get confused in the hospital.

C- The Sodium level is low, and the confusion will resolve as the levels normalize.

D- The sodium level is high and the behavior is a result of dehydration.

7-Which of the following is best to be given for a patient with hypoglycemia ?

A- ½ NS

B- NS

C- D5 ½ NS

D- D10W

8-A decrease in effective arterial blood pressure will lead to:

A- Increased renal absorption of Na

B- Decreased renal absorption of Na

C- Increased renal excretion of Na

D- Decreased stroke volume

Answers:

1.A

2.D

3.B

4.C

5.A

6.C

7.D

8.A

9.B

9- Woman with hypertension on Hydrothiazide came to ER, her Na level is 114. She was given 3% normal saline. Her Na level in the next 24 hours should not exceed?

A- 118

B- 126

C- 130

D- 138