IV fluid & acid base disorder

Objectives:

- Identify types of intravenous fluids.
- Assessing losses in the surgical patient
- Revision of fluid compartments (physiology part) (fluid & substance).
- Prescribing fluids.
- Electrolytes abnormalities.
- Acid-base balance.

Resources:

- Davidson's.
- Slides
- Surgical recall.
- Raslan's notes.

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Once you stop learning
you start dying.

Principles of fluid and electrolytes

• Why it is important?

- Very basic requirements
- Daily basic requirements
- You will be asked to do it as junior staff
- **To maintain patient life**

• Introduction:

- Intravenous (IV) fluids are infused to <u>maintain</u> fluid balance, <u>replace</u> fluid losses, and <u>treat</u> electrolyte imbalances.
- They are commonly available in volumes ranging from 25 mL to 1,000 mL and are dispensed in either plastic bags or glass bottles.

• Intravenous fluids:

- IV fluid is the giving of fluid and substances directly into a **vein.**
- Human Body has fluid and substances.

• Substances that may be infused intravenously:

- **volume expanders (crystalloids and colloids)**
- blood-based products (whole blood, fresh frozen plasma, cryoprecipitate)
- blood substitutes and medications.

Fluid compartments

General information:

- Water makes up around two thirds of our total body mass.
- Total body water (TBW) :
    - **Male:** 60% of body weight (BW).
    - **Female:** 50-55%, because female contain an extra 5% of adipose tissue.
- **<u>To calculate TBW needed:</u>**
    - Male sex TBW= BW× 0.6
    - Female sex TBW= BW × 0.5

Example:
A 70 kg man will contain about 42 liters, and a 70 kg woman will contain nearly 38 liters. The reason of this difference between the sexes is that women contain an extra 5% adipose tissue; the difference is only occasionally of clinical significance.

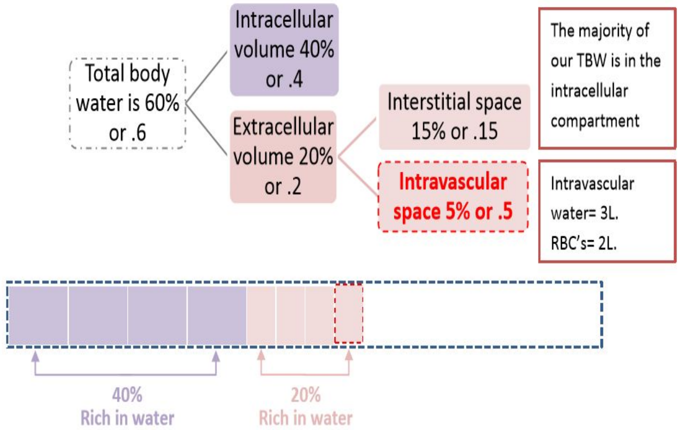
- **Factors that affect our total body fluid:**
- **Age:** the older you get, the more body fluid you lose.
- **Gender:** females have less TBW.
- **Lean body mass (muscle):** increase TBW.
- **Weight:** the higher level of fat, the lower TBW.

Body fluid compartments:

EXAMPLE 1 (How much fluid in your body?)

Important!

- 70 kg male: (70x 0.6), TBW= 42 L
- Intracellular volume = 0.66 x 42 = 28 L
- Extracellular volume = 0.34 x 42 = 14 L
- Interstitial volume = 0.66 x 14 = 9 L
- Intravascular volume = 0.34 x 14 = 5 L



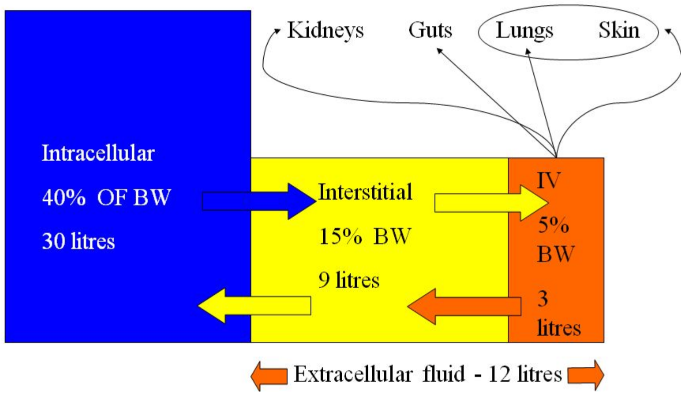
For your knowledge:

*<u>The **intravascular** space is the most important compartment for physicians because:</u>*

- It is the compartment fluid is infused in.
- It absorbs and loses fluid to the interstitial space or to the intracellular compartment.
- Through this compartment almost all significant losses and gains occur.
- We'll see the electrolytes also if the patient is dehydrated by pricking the vessel.

Fluid shifts / intakes:

- Water moves freely between the compartments.
- We lose water through our <u>renal</u> and <u>gastrointestinal tracts</u>, and this **can** be seen and measured.
- The water from our <u>skin</u> and <u>respiratory tract</u> cannot be measured with ease, and makes up our insensible loss. It increases in sickness, particularly when febrile. (but the insensible loss is <u>measurable</u>)



Before we start, check this video it is very helpful [23 min]

Fluids

Types of IV fluid:

	Colloids	Crystalloids
Contents	• Containing **water** and **large proteins** and **molecules.** • Examples: Dextran, hetastarch[1], albumin.	• Containing water and **electrolytes**. No proteins! No albumin! • Contain electrolytes (e.g.,sodium, potassium, calcium, chloride) • **Lack** the large proteins and molecules.(So, not given to a patient with hypoalbuminemia)
Characteristics	• Tend to **stay within the vascular space** and **increase intravascular pressure**. • Colloids are used as a volume expander not for electrolyte imbalance or a physiological condition, just for volume depletion (hypotension) or low albumin. • Very expensive. **When administered:** colloid remains largely within the intravascular space⇒ until the colloid particles are removed by the reticuloendothelial system. Remember, it's big enough to take a tour. The intravascular half-life is usually between 6 and 24 hrs (**long**) and such solutions are therefore appropriate for fluid resuscitation.	• Come in many preparations and volume. • It's important to know the crystalloid's osmolality related to the blood's osmolality. Crystalloid solutions are classified according to their **"Tonicity"** into 3 categories: - **Isotonic:** almost equal tonicity to the plasma e.g. 0.9% NaCl (normal saline), Lactated Ringer's solution and Hartmann's solution. - **Hypotonic:** have lesser tonicity than plasma, e.g. 2.5% dextrose. - **Hypertonic:** have greater tonicity than plasma, e.g. D5 NaCl. **When administered:** The water take a tour across the 3 fluid compartments (ECF, ICF and interstitial) depending on the tonicity*. From HYPER to HYPO.
Uses	• Only For temporary fluid **resuscitation** and for deficit. E.g: Hypoalbuminemia⇒ simply give albumin. Loss of blood⇒ simply give blood. E.g. in case of blood loss, we give albumin (colloid) before blood in hypotensive pts! Why? To increase the BP until the blood come.	1- To correct electrolyte. 2- To maintain the fluid resuscitation.

Basic review:

Tonicity vs osmolality: The terms are different because:

- Osmolarity takes into account the total concentration of (penetrating solutes + non-penetrating solutes).
- Tonicity takes into account the total concentration of (only non-penetrating solutes)
- Osmolality is the dissolution of a solute in whole blood measured in kilograms. Normal blood osmolality = 280-303 milliosmoles/kg.
- Tonicity of a solution Means effective osmolality in relation to plasma (=285 milliosmol/L).

[1] **Hydroxyethyl starch** (**HES/HAES**), sold under the brand name **Voluven** among others, is a nonionic starch derivative, used as a volume expander in intravenous therapy. The use of HES on critically ill patients is associated with an increased risk of death and kidney problems.

Crystalloids solutions:

1- Normal saline (NS) fluid 0.9%:

- **(NS) — is the commonly-used term for a solution of 0.9% weight/volume (w/v) of NaCl.**
- **W/V= about 300 mOsm/L or 9.0 g per liter.** (دائمًا نأخذ الأوزمولالتي، وليس الأوزمولارتي)
- **Na** is 154 and only **Cl** 154
- No K, No others.

2- Lactated Ringer's (Hartmann's) fluid:

One litre of solution contains:

- **Na** = 131 mmol/L.
- **Cl** = 112 mmol/L.
- **lactate** = 29 mmol/L.
- **K** = 5 mmol/L.
- **Ca** = 1 mmol/L

Therefore, its components are **similar to the blood's components**. (MCQs!!).

طيب ليه في الحياة نعطي عادة نورمال سالاين بدل الرنقرز لاكتيت؟ لأن الرنقرز لاكتيت غالي، فعادةً يعطون النورمال سالاين ويقيسون الإلكترولايتس دوريًا، ويضيفون عليه الإلكترولايتس الناقصة (مثل البوتاسيوم) حسب حاجة الجسم له. **Important table below**

Table 1.10 Composition of commonly administered intravenous fluids

	Na^+ (mmol/l)	K^+ (mmol/l)	Cl^- (mmol/l)	HCO_3^- (mmol/l)	Ca^{2+} (mmol/l)	Mg^{2+} (mmol/l)	Oncotic pressure (mmH_2O)	Typical plasma half-life	pH
5% dextrose	–	–	–	–	–		0	–	4.0
0.9% NaCl	154	0	154	0	0		0	–	5.0
Ringer's lactate (Hartmann's solution)	131	5	112	29*	1	1	0	–	6.5
Haemaccel (succinylated gelatin)	145	5.1	145	0	6.25		370	5 hours	7.4
Gelofusine (polygeline gelatin)	154	0.4	125	0	0.4	0.4	465	4 hours	7.4
Hetastarch	154	0	154	0	0		310	17 days	5.5
Human albumin solution 4.5% (HAS)	150	0	120	0	0		275	–	7.4

Calculation of serum osmolality:

- Difficult way: measure & add all active osmoles.
- Easy way = [sodium x 2] + urea + glucose (all in mmol/L)

- Na is the most abundant cation and for each cation there is anion in the serum ex. Cl so we multiply by 2.
- Urea and glucose levels isn't that large in the serum, so we can neglect them (Na x 2 is enough to calculate the serum osmolality)
- **Normal = 280 - 290 mosm / kg**
- We measure it to know if the fluid is isotonic, hypotonic or hypertonic.
- In conditions such as hypernatremia, renal failure (raised urea) or hyperglycemia, osmolality is raised

Electrolytes

Intracellular volume	Extracellular volume
• K+, Mg+, and Phosphate (HPO4-) • **K+** is the **main +ve** <u>intra</u>cellular electrolyte - **Phosphate (HPO4-)** is the main **–ve** <u>intra</u>cellular electrolyte	• Na+, Cl-, Ca++, and Albumin • **Na+** is the **main +ve** <u>extra</u>cellular electrolyte. • **Cl-** is the main **–ve** <u>extra</u>cellular electrolyte

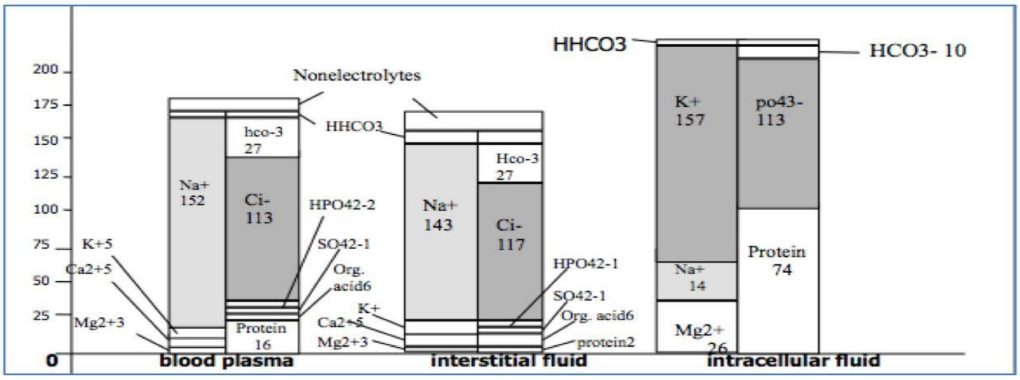


Figure 2: Normal values of electrolytes (know the main cations and anions)

ⓘ Normal electrolyte values:
Serum Na+ = 135 – 147 mmol/L
Serum K+ = 3.5 – 5 mmol/L
Serum Cl⁻ = 98 – 108 mmol/L
Serum HCO_3^- = 20 – 28 mmol/L
Serum Ca^{+2} = 8.5-10.2 mg/dL (~2.2-2.6 mmol/L)

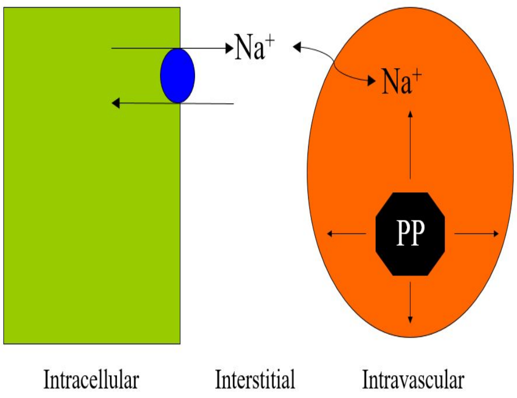
أهم شيء تعرفون في الصورة هي جزئية الـblood plasma .. مهمة في الاختبار!

Recall:

What are the two major body fluid compartments?
Intracellular and extracellular
What are the two subcompartments of extracellular fluid?
Interstitial fluid (in between cells) and Intravascular fluid (plasma)
What percentage of body weight is in fluid?
60% (Intracellular 40% and Extracellular 20%)
What percentage of body fluid is intracellular?
66%
What percentage of body fluid is extracellular?
33%

Osmotic/oncotic pressure, Gibbs–Donnan Equilibrium:"Raslan Notes" - Just Read it for your understanding.

- It refers to the movement of chargeable particles through a semipermeable membrane against its natural location to achieve <u>equal concentrations on either side</u> of the semi permeable membrane.
- For example, movement of Cl- from extracellular space (natural location) to intracellular space (unusual location) in case of **hyperchloremic metabolic acidosis** because negatively charged proteins (natural location in intravascular space) are large molecules that cannot cross the semipermeable membrane for this equilibrium.



The distribution of water throughout depends on:

- **Size** of the compartment available (the bigger the size the more fluid it will get)
- **Tonicity (mainly)**. Water balance is adjusted to maintain osmolality at a constant throughout all three compartments.
- **Oncotic pressure** is generated by large molecules e.g. plasma proteins (PP) and adds to the forces that retain water within the vascular space.

Sodium moves freely between the vascular and interstitial spaces, but is actively extruded (forced out) from the intracellular space; therefore it is the principal extracellular cation.

- It is also the cation that we most frequently administer by giving normal saline (NaCl). When we do this, we increase extracellular **tonicity** and water must move from the intracellular space to the extracellular space to normalize osmolality.
- Electrolytes are exchanged between compartments, if an electrolyte increases in the blood, it will move to the interstitial or intracellular space.
- Some electrolytes move freely, they diffuse via gradients. But some need active transportation e.g. Na+ moves freely extracellularly (between the blood and interstitium), but needs active transport (Na/K pump) to move intracellularly (because this is not its normal position)

Daily requirements of fluid and electrolytes

- Fluid losses in disease and in health are those that can be seen and measured.
- Any fluid lost from the body is potentially in need of replacement, be it urine,stool, or fluid from drains, or other tubes. If possible, measuring these losses is a great help.
- The aim of fluid administration is the maintenance of organ perfusion by keeping TBW at **55 - 60%** this is the **euvolemic state.**
- In order to assess how much fluid should be given to someone, we need to know what their level of hydration is, what losses they may expect, and what gains they may receive (oral intake: fluids, nutritional supplements, bowel preparations – or IV intake: colloids & crystalloids, feeds, drugs)
- **you have to calculate the amount of fluid the person needs before giving him IV fluids.**

How to calculate Fluid Requirements:

- **Fluid requirements = (normal requirement + amount of lost fluid per day + insensible loss)**
- Normal adult requires approximately **35cc/kg/day**[2] (applicable in normal state, there is no fluid loss!)
  - Normal fluid needed = **body weight x 35** (e.g. pt's weight is 100 kg, fluid req. = 100 * 35 = 3500 ml\day)
- You should know if the person has diarrhea or any disease to know how much fluid he has lost.
  - في هذي الحالة، أحسب السوائل اللي طبيعي يحتاجها يوميًا + السوائل المفقودة، وأعطيه الفلويد على أساس الناتج.
- Fever increases insensible loss by **200 cc/day** for **each degree** (C)
- Monitor abnormal GI loss e.g. NGT suctioning (nasogastric tube).
- *Insensible water loss* makes up about **500 ml a day**. It is the amount of fluid lost on a daily basis from the lungs, skin, respiratory tract, and water excreted in the feces. It can be measured but it isn't the exact number

[2] cc⇒ stands for "cubic centimeter (cm^3)". **1cc = 1mL**

Normal daily losses and requirements for fluids and electrolytes:

	Volume (ml)	Na+ (mmol)	K+ (mmol)
Urine	2000	80	60
Insensible losses * (eg. sweating) (skin & resp. tract) 10cc/kg/d	700	--	--
Faeces	300	--	10
Minus endogenous water (water created from metabolism ie. gained water not lost)	300	--	--
Total	2700	80	70

* **Remember, insensible loss is a measurable amount of fluid. والا أجل كيف طلعوا قيمته :) (MCQs!!)**

How to measure how much fluid should be given in an hour:

There are 2 rules:

- Either you find out the normal fluid required and divide it by 24 hours. (e.g. pt's w= 100 kg → 3500 ml/day → 3500/24= 145.8 ml\hr.)
- Or Apply the "4,2,1" Rule ml/hr: Both will give almost the same result, However 4,2,1 is better. We measure it for a fasting patient (NPO= nil per os)

- First 10 kg= 4 cc/kg/hr
- Second 10 kg= 2 cc/kg/hr
- 1cc/kg/hr

→ e.g. pt's w = 100 kg → 4*10 + 2*10 + 1* (100-20) = 140 ml/hr.

Example: How much fluid does a 100 kg male require?
- Daily requirement: 35 cc/kg → 35x100 = 3500 cc/day
- IV fluid rate (per hour), there are 3 methods:
  1) **Divide** 3500 by 24 = 140 cc/hr
  2) **"4, 2, 1" rule:**
     - 1st 10 kg x 4 = 40
     - 2nd 10 kg x 2 = 20
     - 3rd 10 kg x 1 = 10
     - 4th 10 kg x 1 = 10, 5th 10 kg x 1 = 10, 6th 10 kg x1 = 10,…. 10th kg x 1 = 10
     - Total = 40 + 20 + (10 x 8) = 40 + 20 + 80 = 140 cc/hr
  3) **Using the "4, 2, 1" rule**, we can conclude that: body weight + 40 = IVF rate
     - 100 + 40 = 140 cc/hr
     - How does this work? According to 4, 2, 1 rule:
       - You need 40 ml for first 10 kilograms, but you used 1 ml/kg = 1 x 10 = 10 ml → 40 – 10 = 30, so you need to **add 30 ml**
       - You need 20 ml for second 10 kilograms, but you used 1 ml/kg = 1 x 10 = 10 ml → 20 – 10 = 10, so you need to **add 10 ml**
       - Total you need to add is 30 (for 1st 10 kg) + 10 (for 2nd 10 kg) = 40
       - **So body weight + 40 = fluid requirement as calculated by 4, 2, 1 rule**

What is the IV fluid rate?

- In adults: **REMEMBER IVF rate = wt (kg) + 40.**
  - (70 kg + 40 = 110 cc/hr)
- **OR "4,2,1" Rule / hr**[3]

- Assumes no significant renal or cardiac disease and NPO.[4]
- This is the maintenance IVF rate, it must be adjusted(Increased) for any dehydration or ongoing fluid loss.[5]
- Conversely, if the patient is taking fluids PO (by mouth), the IVF rate must be decreased accordingly.

[3] (remember this rule give us the results per hr)
[4] (NPO = nothing by mouth)
[5] we calculated the fluid requirement (either per day or per hr) BUT in calculating the rate it must be (per hr)

Electrolytes requirement

Sodium requirement

- **Na: 1-3 meq/kg/day**

EXAMPLE 1:

- 70 kg male requires (70-210) meq NaCl in 2600 cc fluid per day.
- In such case, you give the patient **half normal saline (0.45% saline).** Why?
- The patient needs 70 – 210 mEq NaCl in 2.6 L a day.
- The half normal saline contains 77 mEq NaCl per liter.
- When you measure it: 77 x 2.6 = 200 mEq, It meets the daily requirement of the patient.
- Unlike giving normal saline which contains 154 mEq NaCl per liter Saline contains 154 meq Na per L⇒ if I gave 2.6 L for NPO patient⇒ 154x2.6= 400.4 meq in 2.6 L > (77-210)."You will kill him!"

(Na: 1-3 meq/kg/day for each kg we need 1-3 meq/kg/d⇒ will give you the result not per L, but as a whole water inside the patient)

- Thus, **0.45% saline** is usually used as MIVF **(maintenance IV fluid)** assuming no other volume or electrolyte issues.

- Ask the pharmacy to send 2.6 L of 0.45% saline contains 77 meq NaCl/liter⇒ 77x2.6= 200.2 meq in 2.6L (200 meq which is exactly what we need here (70-210).

- Or give 1L of NS+ 1L of ½ NS⇒ 231 meq in 2 L almost what we need.. But, this way is too expensive and more complicated..

Example 2:

- Patient weighs 100 kg, requires 100 to 300 mEq NaCl in 3500 cc /d.
- In such case, you give the patient **half normal saline**. Why?
- The patient needs 100 to 300 mEq NaCl in 3.5 L a day.
- The half normal saline contains 77 mEq NaCl per liter.
- When you measure it: 3.5 L x 77 = 269.5 mEq, It meets the daily requirement of the patient.
- Unlike giving normal saline which contains 154 mEq NaCl per liter.3.5x154 it will be 539, it will exceed the amount needed.

Potassium requirement

- **Potassium: 1 mEq/kg/day**

-(the same as Na, but each kg, we need 1 meq of K and here you need to take the rate under consideration)

- **K** can be added to IV fluids. Remember this increases osmolality load.
- **20 meq/L is a common IVF additive.**
- This will supply basal needs in most pts who are NPO.
- If significantly hypokalemia, order separate K supplementation.
- *Oral* potassium supplementation is always ***preferred*** when feasible.
- The most important surgical abnormality is "HYPOkalemia" because they always give fluids but no K+. لأنهم عادة يعطونهم سالاين بدون ما يزيدون البوتاسيوم +
- **Should not be administered at rate greater than 10-20 mmol/hr**[6] Only in the peripheral veins! But **central veins** it is very OK to exceed this rate!!!

-Example: **70 kg male:**

- First you measure the amount of fluid the patient needs per day.
- Then you measure the amount of potassium the patient needs, which is 70 mEq/kg/day of K+.
- After that you'll add the amount of K+ the patient needs to the fluid you chose to give the patient.
- You'll divide it into 20 mEq/L
- This will supply basal needs in most patients who are NPO.
- **It's fine to have higher rate if you infuse in central line (vien).**

[6] It can cause thrombophlebitis = an inflammatory process that causes a blood clot to form and block one or more veins

CASE FOR PRACTICE:

- **FLUID: 35/KG/DAY, Na: 1-3 meq/kg/day, K: 1 meq/kg/day**

- 70 kg male requires 2450 cc fluid per day, 70-210 meq Na
- 0.45% saline contains 77 meq NaCl per liter.
- 0.6 x 77 = 200 meq
- Thus, 0.45% saline is usually used as MIVF assuming no other volume or electrolyte issues.

Fluid shifts in disease:

Fluid loss	Fluid gain
Hypovolemia, when total body water is deficient, is not compatible with normal organ perfusion. Causes of hypovolemia include: ● GI: diarrhoea, vomiting, etc. ● Renal: diuresis ● Vascular: haemorrhage ● Skin: burns	**Hypervolemia,** when body water is in excess, is occasionally necessary for organ perfusion, but is usually harmful. Causes of hypervolemia include: ● Iatrogenic ● Heart / liver / kidney failure

Recall:

what percentage of ideal body weight does blood account for in adults?
≈ 7%
How many liters of blood are in a 70-kg man?
0.07 x 70 = 5 liters
What are the fluid requirements every 24 hours for each of the following substances:
Water ≈ 30 to 35 mL/kg
Potassium ≈ 1 mEq/kg
Chloride ≈ 1.5 mEq/kg
Sodium ≈ 1–2 mEq/kg
What are the levels and sources of normal daily water loss?
Urine ≈ 1200 to 1500 mL (25–30 mL/kg)
Sweat ≈ 200 to 400 mL
Respiratory losses ≈ 500 to 700 mL
Feces ≈ 100 to 200 mL
What are the levels and sources of normal daily electrolyte loss?
Sodium and potassium ≈ 100 mEq
Chloride ≈ 150 mEq
What are the levels of sodium and chloride in sweat?
≈ 40 mEq/L
What is the major electrolyte in colonic feculent[7] fluid?
Potassium ≈ 65 mEq/L

[7] Feces

Prescribing fluids

Crystalloids (Iso, hyop , hypertonic)	Colloids
• **0.9% saline - not " normal " !** • **5% dextrose** **<u>Which are the most commonly used?</u>** • 0.18% saline + 0.45% dextrose • Others	• Blood. • Plasma / albumin • Synthetics

The rules of fluid replacement:

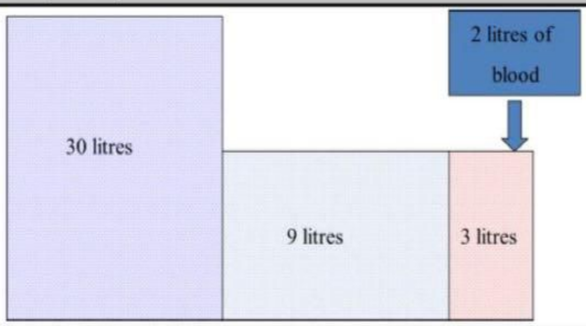
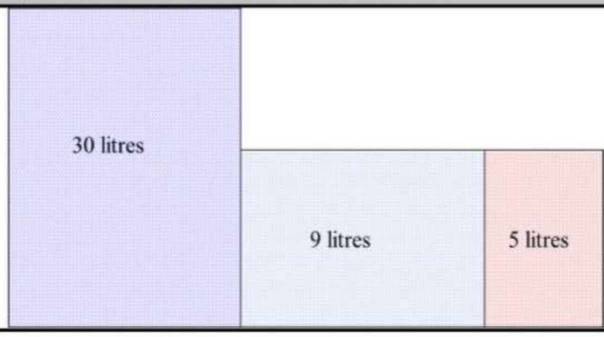
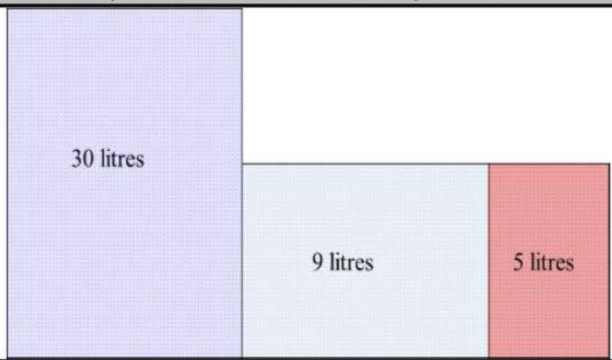
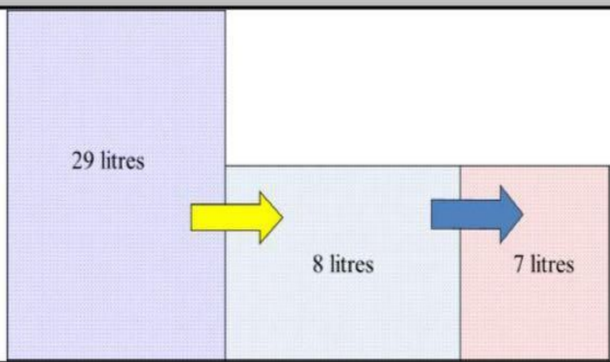
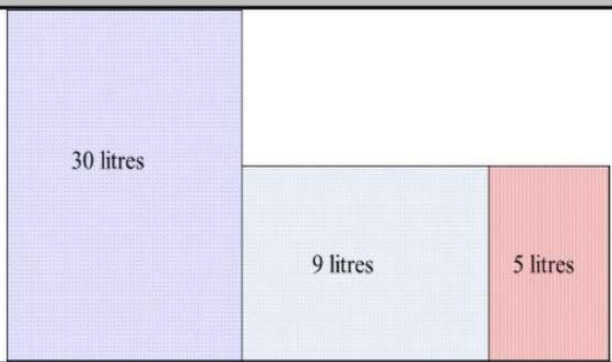
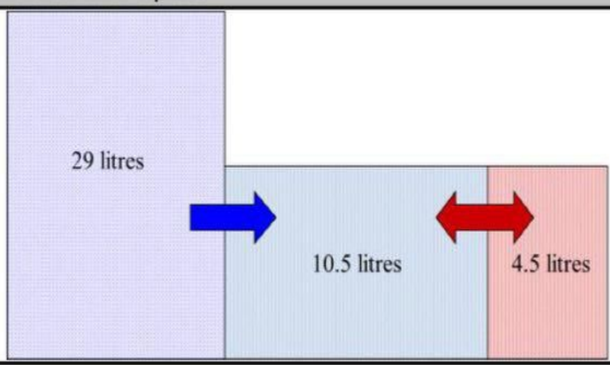
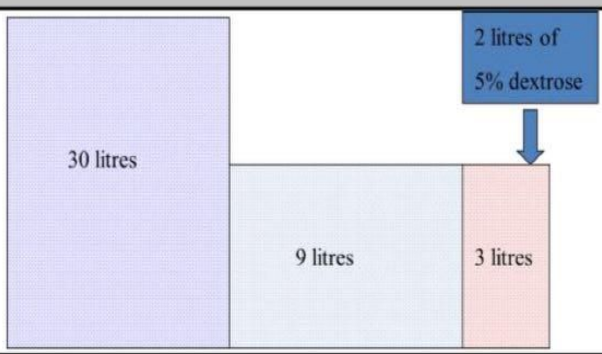
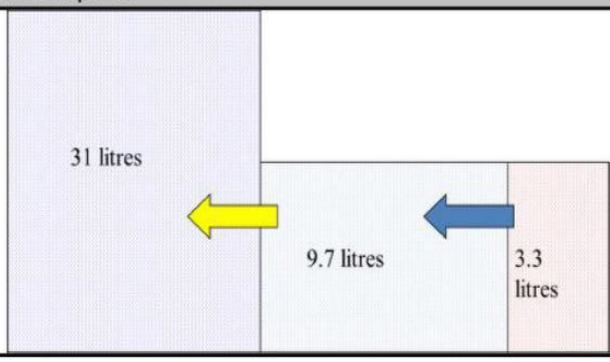
Raslan Notes: "JUST READ IT"

What IV fluid to give, in what situation is dealt with in the next series of slides. There are some basic rules though:

- Someone with serious intravascular volume depletion, hypotension and reduced cardiac output is shocked, be it from blood loss (eg. haemorrhage), plasma loss (eg. major burns), or water loss. The aim here is to restore intravascular volume with a fluid that remains in the vascular compartment, and may even draw water from the intracellular space, into the blood system. A fluid with a high oncotic pressure would do this job. **Blood remains the fluid of choice to treat someone with blood loss. Colloid is the fluid of choice in resuscitation when blood loss is not pronounced, or whilst waiting for blood.**
- Any crystalloid will enter the vascular space, then distribute around the other compartments. By containing sodium, the main extracellular cation, saline will expand the interstitial and intravascular compartments more than will dextrose, most of which will enter the intracellular space.
- The right treatment for blood loss is to replace it with blood. Giving 2 liters of blood to someone will expand their intravascular compartment by 2 liters. None of this fluid will escape across the blood vessel walls (in the short term at least) and the other compartments are unaffected.
- Giving colloid into the vascular space results in an immediate expansion of the intravascular compartment by 2 liters (like blood). Colloid does not escape from the vascular space, but does increase oncotic pressure markedly causing water to be drawn into the vascular space from the interstitial and intracellular reservoirs. Giving colloid not only expands the vascular space itself, but does so by moving water from other spaces.
- Saline being a crystalloid, does not remain within the vascular space, but will diffuse into the interstitial space. The sodium it carries will not enter the intracellular space however, because of active sodium extrusion from the cell. Saline will cause immediate expansion of the intravascular volume, followed by equilibration between the vascular and interstitial spaces, the osmolality of which are equal, but are now slightly greater than that of the intracellular space, due to the increased sodium load. This results in water movement from the intracellular space in order to equalize osmolality throughout all three compartments.
- 5% Dextrose is isotonic to plasma. Giving 2 liters of 5% dextrose will cause the immediate expansion of the vascular compartment but as its glucose content is rapidly metabolized, the remaining water will distribute itself between all compartments and very little will remain within the blood space. For this simple reason, **dextrose is not a fluid of resuscitation.**

<u>In summary:</u>

- Replace blood with blood.
- Replace plasma with colloid.
- Resuscitated with colloid.
- Replace ECF depletion with saline.
- Rehydrate with dextrose."Dextrose should be given in case of dehydration"
- The only thing that goes intracellularly is the potassium.

2L of **blood**:	Stays in the intravascular compartment
	
2L of **colloid**: immediate expansion of intravascular space& increases oncotic pressure	+ draws water from other compartments
	
2L of **crystalloid**: immediate expansion of vascular compartment	Then: equilibration between the vascular and interstitial spaces, and draws water from intracellular space
	
2L of 5% **dextrose**: immediate expansion of vascular compartment	Then: glucose content is rapidly metabolized, remaining water will distribute itself between all compartments and very little will remain within the blood space
	

How much fluid to give?

- What is your starting point ?
- Euvolemia? (normal)
- Hypovolaemia? (dry)
- Hypervolaemia? (wet)

Extra Notes:

- The aim of fluid administration is the maintenance of organ perfusion by keeping total body water at 55 - 60% - this is the euvolaemic state.
- Hypovolaemia, when total body water is deficient is not compatible with normal organ perfusion; hypervolaemia, when body water is in excess, is occasionally necessary for organ perfusion, but is usually deleterious.
- In order to assess how much fluid to give to someone, we need to know what their level of hydration is, what losses they may expect, and what gains they may receive.

What are the expected losses?

- Measurable:
- Urine (measure hourly if necessary)
- GI (stool, stoma, drains, tubes)
- Insensible:
- Sweat.
- Exhaled.

Extra Notes:

- Any fluid lost from the body is potentially in need of replacement, be it urine, stool, or fluid from drains, or other tubes. If possible, measuring these losses is a great help.
- Insensible losses make up about 500 ml a day in health. In febrile illnesses, insensible losses increase by 100 ml / day / degree centigrade.

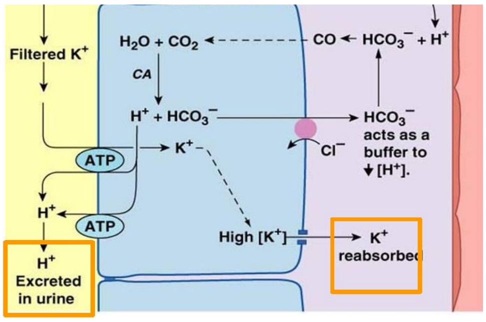
What are the potential gains?

- **Oral intake:**
- Fluids
- Nutritional supplements
- Bowel preparations
- **IV intake:**
- Colloids & crystalloids
- Feeds & Drugs.

Extra Notes:

- Fluid gains are simple; anything that is taken in is a potential gain, be it intravenous, oral or other.
- Remember that a large amount of food is broken down, or melts into water, so this may need to be counted as well.

Electrolytes Abnormalities

Potassium		
Diagnosis	**Hypokalaemia**	**Hyperkalemia** (arrhythmias presentations)
	• **Serum K+ < 3 mEq/L**	• **Serum K+ > 6 meq/L and ECG changes.** (bradycardia and peaked T wave)
Causes	**The most common surgical abnormality.** • **Reduced/inadequate intake** **Gastrointestinal tract losses:** - Vomiting - Gastric aspiration/drainage. [8] - Fistulae.[9] - **Diarrhoea** - Ileus. [10] - Intestinal obstruction - Potassium-secreting villous adenomas - Any mucous = K+ loss. • **Urinary losses:** - Metabolic **alkalosis** (shifts K+ to intracellular compartment) - Hyperaldosteronism. (promotes K+ excretion in kidneys) ADH & Aldosterone are the most imp hormones in electrolytes. - Diuretic use (e.g. Lasix) - Renal tubular disorders(e.g. bartter's syndrome[11], renal tubular acidosis, amphotericin-induced tubular damage) **Symptoms:** weakness and fatigue (most common), muscle cramps and pain (severe cases), altered level of consciousness, arrhythmias.	• Increase K+ infusion in IVF • Tissue injury. Any cells destruction results in hyperkalemia. • Metabolic **acidosis** (causes a shift of potassium from intracellular space into extracellular space) • تذكروا حالة الDKA يصير عندي hyperkalemia :) • Renal failure (↓ excretion) • Blood transfusion (RBCs contain high conc of K+) • Hemodialysis. • Haemolysis • Rhabdomyolysis • Massive tissue damage • Acidosis - ARF 
Treatment	• Treatment involves **KCl** i.v. infusion or orally. • Should **NOT** be administered at rate **greater than 10-20 mmol/hr.**	• **Insulin:** 10 IU (shifts K+ back into intracellular compartment) + glucose: 1 ampule of Dextrose 50% (prevent hypoglycemia from insulin) over 15 minutes • calcium oxalate enemas (Given orally) • Lasix 20-40 mg I.V. • And dialysis if needed. • Do ECG.

[8] (the flow of gastric content into the upper respiratory tract due to a ↓ antireflux reflex)

[9] (an abnormal connection between an organ, vessel, or intestine and another structure. It's usually the result of injury, surgery, infection or inflammation)

[10] (disruption of the normal propulsive gastrointestinal tract that causes obstruction which prevents bowel contents, such as stool,fluid and gas, from moving through the intestine, which becomes distended)

[11] is a rare inherited defect in the thick ascending limb of the loop of Henle. It is characterized by low potassium levels (hypokalemia),increased blood pH (alkalosis), and normal to low blood pressure. There are two types of Bartter syndrome: neonatal and classic. A closely associated disorder, Gitelman syndrome, is milder than both subtypes of Bartter syndrome.

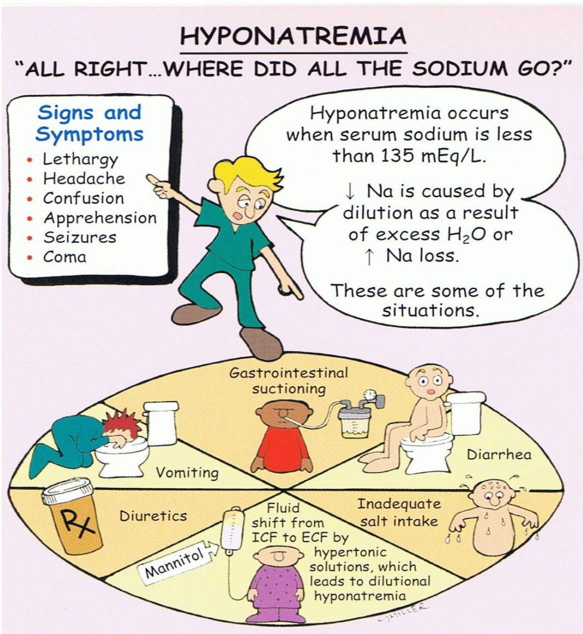
<table>
<tr><th colspan="3">Sodium</th></tr>
<tr><td rowspan="2">Diagnosis</td><td>Hypo natremia “Sodium Deficit”</td><td>Hyper natremia “Sodium Excess”</td></tr>
<tr><td>• <135 mmol/L</td><td>• > 145mEq/L
This is primarily caused by high sodium infusion (e.g. 0.9% or 3% NaCl saline solutions).</td></tr>
<tr><td>Causes</td><td>• Hyperglycemia. → causes pseudo-hypoNa.
لأن السكر العالي في الدم يسحب المويه معه ويقلل تركيز الصوديوم

Corrected Na= BS mg/dl x 0.016 + P(Na) | BS: blood sugar.
Can be volume overload, normo, low.

This equation is used to differentiate between pseudo-hyponatremia and true Hyponatremia.

• Excessive IV sodium-free fluid administration.(hypotonic solutions)

Hyponatremia with volume <u>overload</u> “hypervolemic hyponatremia” usually indicates impaired renal ability to excrete sodium.


</td><td>• Reduced intake:
- Fasting
- Nausea and vomiting
- Ileus
- Reduced conscious level
• Increased loss:
- Sweating (pyrexia, hot environment)
- Respiratory tract loss (increased ventilation, administration of dry gases)
- Burns
• Inappropriate urinary water loss:
- Diabetes insipidus (pituitary or nephrogenic)
- Diabetes mellitus[12]
- Excessive sodium load (hypertonic fluids, parenteral nutrition)
- Another but <u>rare</u> cause is hyperaldosteronism. (aldosterone promotes water and Na retention)
- Patients with CHF, Cirrhosis, and nephrotic syndrome are prone to this complication.

“Symptoms and sign of are similar to water excess. includes coma, convulsions and confusion.”</td></tr>
<tr><td>Treatment
MCQs!</td><td>• Administering the calculated sodium needs in <u>isotonic</u> solution.
• In <u>severe hyponatremia</u> (Na less than 120meq/l): give hypertonic sodium solution.
• <u>Rapid correction</u> may cause permanent brain damage duo to the osmotic demyelination syndrome (bc cells get shrinked!! Irreversible damage!)
• Serum Na should be increased at a rate not exceed 10-12meq/L/h.

Before treating hyponatremia, you should check if it’s true hyponatremia or pseudohyponatremia by checking the glucose levels. The glucose levels should be corrected in case of pseudohyponatremia, no further treatment is needed.</td><td>• Treatment include water intake and ↓ sodium infusion in IVF (e.g. 0.45% NaCl or D5%Water).</td></tr>
</table>

[12] Late stage

Water

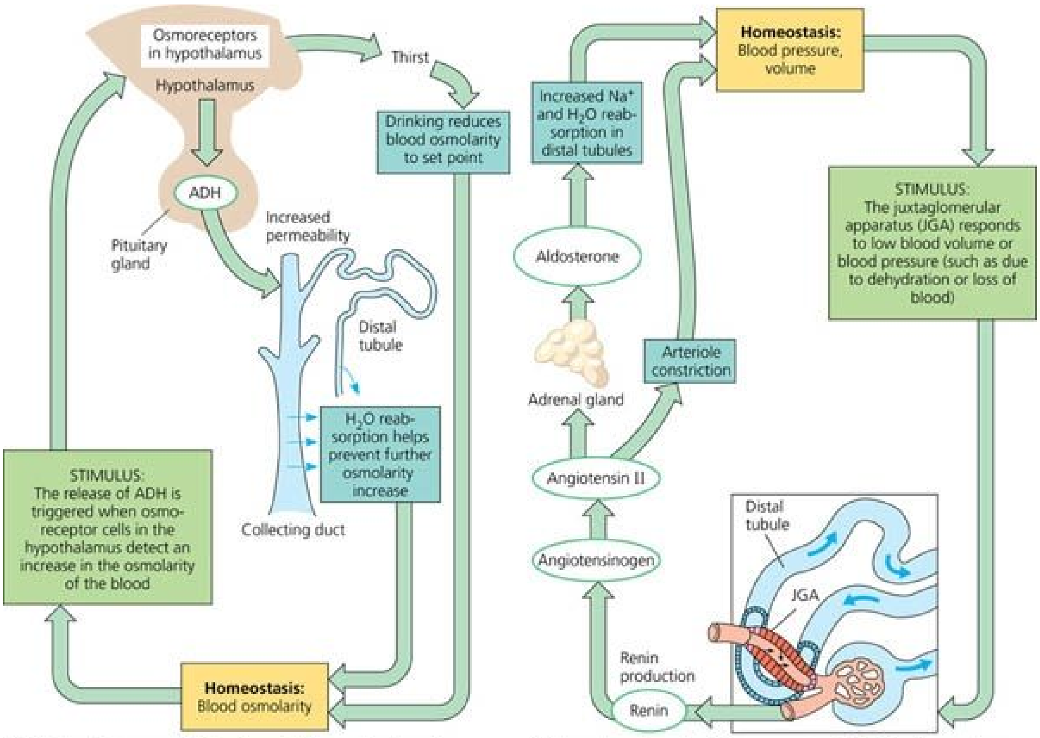
	Water excess	Water deficit
Diagnosis	• Diagnosis of **SIADH** secretion is established when **urine sodium > 20** mEq/L when there is **no renal failure, hypotension, and edema.**	• Diagnosis can be confirmed by ↑ serum sodium (>145 mEq/L) and ↑ serum osmolality (>300 mOsmol/L)
Causes	• Inappropriate use of **hypotonic solutions** (e.g. D5%Water) leading to hypo-osmolar hyponatremia, and **Syndrome of inappropriate antidiuretic hormone secretion (SIADH)** **SIADH causes:** malignant tumors, CNS diseases, pulmonary disorders,medications, and severe stress.	**"The most encountered derangement of fluid balance in surgical patients"** Most common cause: simply u didnt give the pts water :) - Bleeding - Third spacing (is the shift of fluid from the intravascular space to a nonfunctional space, or the loss of extracellular fluid from the vascular to other body compartments) - Gastrointestinal losses. - Increase insensible loss (normal ≈ 10ml/kg/day) Insensible loss is <u>measurable</u> :) - Increase renal losses (normal ≈ 500-1500 ml/day).
Symptoms	• Symptoms of water excess develop **<u>slowly</u>** and if not recognized and treated promptly, they become evident by **convulsions and coma due to <u>cerebral edema</u>.**	• Feeling thirsty. • Dryness. • Lethargy. • Confusion.
Signs	• **Signs of volume overload:** - Hypertension - Tachycardia - Raised JVP / gallop rh - Oedema - Pleural effusions - Pulmonary oedema - Ascites - Organ failure. • The signs of volume depletion or overload can be subtle. Note that some appear in both - especially **tachycardia.**	• **Signs of volume depletion:** - Dry tongue and mucous membranes, sunken eyes, dry skin, loss of skin turgor, collapsed veins, depressed level of consciousness, and coma. - Postural hypotension.(where blood pressure falls on standing or sitting up is a reliable early sign of hypovolemia, which is often not checked) - Absence of JVP @ 45 degree - Supine hypotension. - Oliguria, Organ failure, Tachycardia
Treatment	• **<u>Water restriction</u>** and infusion of isotonic or hypertonic saline solution. • **In SIADH:** ○ Treatment involves restriction of water intake (<1000 ml/day) ○ Use of ADH- Antagonist (Demeclocycline 300-600 mg b.i.d). ○ Measure Na in the urine, if high, sodium is concentrated → high ADH. If normal Na → ADH is not increased!!	- If sodium is > 145mEq/L give 0.45% hypotonic saline solution. - If sodium is >160mEq/L give D5%Water **cautiously and <u>slowly</u>** (e.g. 1liter over 2-4 hours) in order not to cause water excess. - Bleeding should be replaced by IVF initially then by whole blood or packed red cells depending on hemoglobin level. Each blood unit will raise the hemoglobin level by 1 g. - Third spacing replacement can be estimated within a range of 4-8 ml/kg/h. - Gastrointestinal and intraoperative losses should be replaced cc/cc. - IVF maintenance can be roughly estimated as 4/2/1 rule.

The role of ADH:

- ADH = urinary concentration.
- ADH = secreted in response to ↑ osmo = secreted in response to ↓ volume.
- ADH acts on DCT[13] / CD[14] to reabsorb water
- Acts via V2 receptors & aquaporin 2
- Acts only on **WATER.**

Extra Notes:

- The principle mechanism by which osmolality is maintained is by changes in ADH secretion from the posterior pituitary.
- Antidiuretic hormone secretion results in **pure water reabsorption** from the collecting duct of the nephron via a pathway that involves the V2 receptor and aquaporin 2.
- **A rise in plasma osmolality increases ADH secretion**, whilst a decrease causes ADH secretion to fall.
- ADH secretion is also influenced by volume receptors, so that hypovolemia stimulates ADH secretion and water reabsorption.
- In the paradoxical situation where hypovolemia is accompanied by a fall in osmolality, ADH secretion will increase.
- The major stimulant is maintenance of normovolemia.

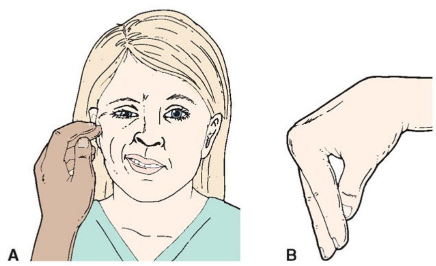


(a) Antidiuretic hormone (ADH) enhances fluid retention by making the kidneys reclaim more water.

(b) The renin-angiotensin-aldosterone system (RAAS) leads to an increase in blood volume and pressure.

[13] distal convoluted tubule
[14] Collecting duct

Calcium

Diagnosis	**Hyper calcemia**	**Hypo calcemia**
	• Diagnosis is established by measuring the <u>free</u> Ca++>10mg/dl.	----
Causes	• In <u>surgical</u> patients hypercalcemia is usually caused by **<u>hyperparathyroidism</u>** and **malignancy.**	- Results from **Hypoparathyroidism** after thyroid or parathyroid surgeries, - Low vitamin D. - Other <u>less common causes</u> include pancreatitis, necrotizing fasciitis, high output G.I. fistula, and massive blood transfusion. - **Pseudohypocalcemia (<u>low albumin</u> and hyperventilation).** - Blood transfusion المادة الحافظة ترتبط بالكالسيوم ويصير عندي هيبوكالسيميا، في حالة نقل الدم، لازم أعطي معه كالسيوم! *Hypoalbuminemia:the relation between Ca++ and albumin is the binding of the Ca++ to albumin which makes the calcium less free.In hypoalbuminemia total calcium is ↓ while ionized is unaffected. *Hyperventilation→respiratory alkalosis→ ↑Ca binding to albumin & ↓ free Ca
Symptoms & Signs	**Symptoms:** • Confusion, weakness, lethargy, anorexia, vomiting. • Epigastric abdominal pain due to pancreatitis. • Polyuria due to Nephrogenic diabetes insipidus polyuria. Hypo-reflexia.	**Symptoms:** - <u>Numbness</u> and tingling sensation circumorally or at the fingers' tips. - <u>Tetany</u> and seizures may occur at a very low calcium level. **Signs:** - Tremor, hyper-reflexia. - Positive **Chvostek sign**. (A) - Carpopedal spasms. (B) 
Treatment	• Treatment includes **normal saline infusion** (initial tx) • And if Ca++>14mg/dl <u>with ECG changes</u> additional diuretics, calcitonin, and mithramycin might be necessary + beta-blockers.	• Treatment should start by treating the cause. • Calcium supplementation with calcium gluconate or calcium carbonate i.v. or orally. • Vitamin D supplementation especially in chronic cases.

Magnesium		
	Hyper magnesaemia	**Hypo magnesaemia**
Causes	• Mostly occur in association with renal failure, when Mg++ excretion is impaired. • The use of **antacids** containing Mg++ may **aggravate hypermagnesaemia.**	- The majority of magnesium is intracellular with only <1% is in extracellular space. "It happens from inadequate replacement in depleted surgical patients with **major GI fistula** and those on **TPN**." "Total parenteral nutrition" - **Magnesium is important for neuromuscular activities. (can not correct K nor Ca)** - In surgical patients hypomagnesaemia is a frequently missed common electrolyte abnormality as **it causes no major alerting symptoms.**
Treatment	• Treatment includes **rehydration and renal dialysis.**	**----**

Phosphate		
	Hyper phosphataemia	**Hypo phosphataemia**
Causes	• Mostly is associated with **renal failure** and **hypocalcaemia** due to <u>hypo</u>parathyroidism, which reduces renal phosphate excretion.	**This condition may result from:** - Inadequate intestinal absorption. - Increased renal excretion. - Hyperparathyroidism PTH goes to the bones, destruct them, secretes phosphate in the urine! - **Massive liver resection** the most electrolyte deficit in this condition is phosphate!!!! - Inadequate replacement after recovery from significant starvation and catabolism.
Treatment		• Hypophosphataemia causes muscle weakness and inadequate tissue oxygenation <u>due to reduced 2,3- diphosphoglycerate levels</u>. • **Early recognition and replacement will improve these symptoms.**

Mg and phosphate abnormalities occur with chronic diseases, before replacing them check the renal system, caused all the time by renal failure.

Acid-base balance

Normal physiology:

- Hydrogen ion is generated in the body by:
    1. Protein and CHO metabolism (1 mEq/kg of body weight)
    2. Predominant CO_2 production
- It is mainly intracellular

acidosis	Norma pH	alkalosis
< 7.3	7.3 - 7.42	> 7.42

- pH = log $1/[H^+]$ That's mean increase numbers of proton will decrease pH.

Buffers[15]:

*<u>1- Mechanisms to maintain the normal value of pH in the **intracellular fluid:**</u>*

- **Protein**, which include **hemoglobin**: Protein buffers include basic group, and acidic protein buffer groups, that act as hydrogen ion depletors or donors to maintain the pH level at 7.4
- **Phosphate,** when H concentrations increase, it binds to H ions and is excreted in the urine with sodium.

*<u>2- Mechanisms to maintain the normal value of the PH in the **extracellular fluid:**</u>*

- **Bicarbonate/carbonic acid system:** → **the main mechanism**
- pH levels depend on **CO_2** and **HCO_3** mainly **($H^+ + HCO_3 \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_2O$)**
- Hydrogen ions and the bicarbonate form carbonic acid which forms CO_2 and water under the enzyme **carbonic anhydrase.**
- So if hydrogen ions increase in the plasma, CO_2 production will increase therefore the pH will decrease.

Arterial/venous blood gases			
pH	7.3 - 7.42	**PCO2**	40 mmHg
PO2	65 mmHg	**O2 saturation**	≥ 90%
HCO3	24 mEq/L	**Base excess**	2.5 (<2.5 metabolic acidosis, >2.5 metabolic alkalosis)
Anion Gap (AG)	12 (>12 met. acidosis, < 12 met. alkalosis)		

كيف أقرأ الA/VBG؟ أول شيء أشوف الpH ، إذا acidic ، أشيك على pCO2 ، إذا نورمال = يعني مو resp. Acidosis إنما met. Acidosis .. و لأنه ميتابولك، فأروح أحسب الanion gap (نتذكر إننا ما نحسب الأنيون قاب إلا لما يصير عندنا met. Acidosis)

- **Anion Gap:**
- AG= Cations (NA+ K) – Anions (CL + HCO_3)
- Normal value is 12 mmol
- Metabolic acidosis with:

1- Normal AG (Diarrhea, Renal tubular acidosis)

2- High AG

- Endogenous (Renal failure, diabetic acidosis, sepsis)
- Exogenous (aspirin, methanol, ethylene glycol)

[15] Mechanisms to maintain the normal value of pH

Metabolic acidosis	Metabolic alkalosis
Low pH due to H+ ions accumulation and HCO3 ions decrease. To know the cause of metabolic acidosis you have to calculate the anion gap : **(AG) =** Cations (NA+ K) – Anions (CL + HCO3) **Causes :** *1-Normal AG:* (Diarrhea, Renal tubular acidosis) *2-High AG:* - Endogenous (Renal failure, diabetic acidosis, sepsis) - Exogenous (aspirin, methanol, ethylene glycol) **Lactic acidosis** - Shock (any cause) - Severe hypoxaemia - Severe haemorrhage/anaemia - Liver failure **Accumulation of other acids** - Diabetic ketoacidosis - Acute or chronic renal failure - Poisoning (ethylene glycol, methanol, salicylates) **Increased bicarbonate loss** - Diarrhoea , Intestinal fistulae	• **Loss of sodium, chloride, water:** vomiting, NGT[16], LASIX • Hypokalaemia[17] • HCO3 retention.
Respiratory acidosis[18]	**Respiratory alkalosis[19]**
Common surgical causes of respiratory acidosis **Central respiratory depression** - Opioid drugs - Head injury or intracranial pathology **Pulmonary disease** - Severe asthma - COPD - Severe chest infection	- Pain - apprehension/hysterical hyperventilation - Pneumonia - CNS disorders (meningitis, encephalopathy) - Pulmonary embolism - Septicaemia - Salicylate poisoning - Liver failure

Recall :

What are the surgical causes of the following conditions:
- Metabolic acidosis
Loss of bicarbonate: diarrhea, ileus, fistula, high-output ileostomy, carbonic anhydrase inhibitors
Increase in acids: lactic acidosis (ischemia), ketoacidosis, renal failure, necrotic tissue
- Metabolic alkalosis
Vomiting, NG suction, diuretics, alkali ingestion, mineralocorticoid excess
- Respiratory acidosis
Hypoventilation (e.g., CNS depression), drugs (e.g., morphine), PTX, pleural effusion, parenchymal lung disease, acute airway obstruction
- Respiratory alkalosis
Hyperventilation (e.g., anxiety, pain, fever, wrong ventilator settings)
What is the "classic" acid-base finding with significant vomiting or NGT suctioning?
Hypokalemic hypochloremic metabolic alkalosis
What is the treatment for hypokalemic hypochloremic metabolic alkalosis?
IVF, Cl /K replacement (e.g., N.S. with KCl)
Why hypokalemia with NGT suctioning?
Loss in gastric fluid - loss of HCl causes alkalosis, driving K into cells

[16] nasogastric tube
[17] If you lose K, you will get alkalosis. If you gain you will get acidosis.
[18] anything that causes **hypoventilation**
[19] anything that causes **hyperventilation**

Case 1:

- **A 62 year old man is 2 days post-colectomy. He is euvolaemic, and is allowed to drink 500ml. His urine output is 63 ml/hour:**

1. How much IV fluid does he need today?
2. What type of IV fluid does he need?

Explanation:

- This man has a normal total body water content, and you aim is to maintain that.
- A urine output of 63 ml / hr gives him a total daily urine loss of 1.5 litres. His **insensible losses** are likely to be 500 ml. He therefore needs a total fluid intake of 2 litres to balance his losses. He is only allowed to drink 500 ml.
- He therefore needs 1.5 litres of fluid IV today.
- As he is euvolaemic, this man does not need resuscitation, so he should only receive crystalloid. His losses will include water and electrolytes. Giving him just 5% dextrose will cause osmolality to fall and hyponatraemia to follow. Giving him just 0.9% saline will cause gradual hypernatraemia and hypertonicity.
- This man needs a mixture of crystalloids. He is getting water orally which might help to offset the sodium load of saline. Even so, it is reasonable to use saline and dextrose in a 2:1 ratio; this proportion can be changed in response to changes in his clinical state and serum sodium.

Case 2:

- **3 days after her admission, a 43 year old woman with diabetic ketoacidosis has a blood pressure of 88/46 mmHg & pulse of 110 bpm. Her charts show that her urine output over the last 3 days was 26.5 litres, whilst her total intake was 18 litres:**

1. How much fluid does she need to regain a normal BP?
2. What fluids would you use?

Explanation:

- The hyperglycaemia of diabetic ketoacidosis causes glycosuria which results in an osmotic diuresis. This causes high losses of water and dehydration occurs if fluid balance is not attended to.
- In this case, the lady has lost 26.5 litres of urine plus at least 1.5 litres insensible losses over the last 3 days; her input has been 18 litres. This equals a deficit of 10 litres, and it is not surprising that she appears to be hypovolaemic with hypotension and tachycardia.
- Assuming that she was euvolaemic to start with, she needs to gain 10 litres in order to regain a normal BP.
- As she has a low BP, we can assume that her blood volume is low, and that organ perfusion is at risk. She therefore needs to be resuscitated. The initial fluids to use would be colloid in order to normalise BP and pulse. There is no need to use only colloid; indeed, this would cause intravascular overload and heart failure. After using perhaps 1 or 2 litres of colloid, her remaining fluids should be crystalloid. As she has lost mainly water, a large part of this should be dextrose, and serum [Na^+] should be monitored in order to assess the need for IV saline.

Case 3:

- **An 85 year old man receives IV fluids for 3 days following a stroke; he is not allowed to eat. He has ankle oedema and a JVP of +5 cms; his charts reveal a total input of 9 l and a urine output of 6 litres over these 3 days.**

1. How much excess fluid does he carry?
2. What would you do with his IV fluids?

Explanation:

- This man has become hypervolaemic with interstitial oedema and intravscular excess, becuase he has received 3 litres more fluid than he has passed out in his urine. Remember however that he loses 500 ml / day insensible losses.
- His total fluid excess is therefore around 1.5 litres.
- Although he is not drinking, he is overloaded and his IV fluids should be stopped. After a day without IV fluids, he should be euvolaemic, and IV fluids can be recommenced at 2.5 litres a day without overloading him.

Case 4:

- **5 days after a liver transplant, a 48 year old man has a pyrexia of 40.8oC. His charts for the last 24 hours reveal:**

Urine output:	**2.7 litres**
Drain output:	**525 ml**
Nasogastric output:	**1.475 litres**
Blood transfusion:	**2 units (350 ml each)**
IV crystalloid:	**2.5 litres**
Oral fluids:	**500 ml**

- **On examination he is tachycardic; his supine BP is OK, but you can't sit him up to check his erect BP. His serum [Na+] is 140 mmol/l.**

How much IV fluid does he need?
What fluid would you use?

Explanation:

- This is a bit more complex !
- As is often the case with complex surgical patients, this man has multiple sources of fluid loss. In each case, urine, drain or tube, the fluid lost will be a mixture of fluid and solutes. Indeed, drain fluid will have an electrolyte content very similar to plasma.
- His obvious losses (urine + drain + NG tube) total 4.7 litres.
- His insensible losses are higher than normal because of his fever, and will be about 800 ml, giving a total loss of 5.5 litres.
- His total intake was 3.7 litres, and he is therefore deficient by 1.8 litres.
- Assuming that his total losses for this day are similar to those of the day before, he will need about 7.3 litres in order to become euvolemic.
- He will almost undoubtedly need a mixture of fluids. He will need colloid or further blood in order to fill the intravascular compartment and maintain organ perfusion. He will need saline to replace water and solute losses, and will need some dextrose in order to prevent hypernatraemia.
- In practice, a case of this complexity will require repeated re-evaluation, adjustment of his fluids throughout the day with serial blood tests in order to guide you.
- If you can follow this one, you've cracked it !

Terminologies: just read it :)

	Definitions
Solvent	is the liquid where particles dissolves in (e.g. Water) that can be measured in liters and milliliters.
Solutes	are the dissolving particles
molecule	is the smallest unit with chemical identity (e.g. Water consist of one oxygen and two hydrogen atoms = water molecule)
Ions	are dissociated molecule into parts that have electrical charges (e.g. NaCl dissociates into Na+ and Cl-)
Cations	are positively charged ions (e.g. Na+) due to loss of an electron (e-)
anions	are negatively charged ions (e.g. Cl-) due to gain of an electrone (e-)
Electrolytes	are interacting cations and anions (e.g. H+ + Cl- = HCL [hydrochloric acid])
univalent	ion has one electrical charge (e.g. Na+). A divalent ion has two electrical charges (e.g. Ca++)
Molecular weight	is the sum of atomic weights of different parts of a molecule (e.g. H+ [2 atoms] + O2 [16 atoms] = H2O [18 atoms])
mole	is a measuring unit of the weight of each substance` in grams (e.g. 1 mole of Na+ = 23 grams, 1 mole of Cl- = 35 grams, 1 mole of NaCl = 58 grams). It can be expressed in moles/L, millimoles x 10-3/L, micromoles x 10-6/L of the solvent.
Equivalence	refers to the ionic weight of an electrolyte to the number of charges it carries (e.g. 1 mole of Na+ = 1 Equivalent, whereas 1 mole of Ca++ = 2 Equivalents). Like moles, equivalence can also be expressed in milliequivalent/L and microequivalent/L of the solvent.
Osmosis	is the movement of a solution (e.g. water) through a semipermeable membrane from the lower concentration to the higher concentration.
Osmole/L or milliosmole/L	is a measuring unit for the dissolution of a solute in a solvent
Osmotic coefficient	means the degree of dissolution of solutes (molecules) in a solvent (solution). For example the osmotic coefficient of NaCl is 0.9 means that if 10 molecules of NaCl are dissolved in water, 9 molecules will dissolve and 1 molecule will not dissolve.
Osmolarity	is the dissolution of a solute in plasma measured in liters, whereas
Osmolality	is the dissolution of a solute in whole blood measured in kilograms. Therefore, Osmolality is more accurate term because dissolution of a solute in plasma is less inclusive when compared to whole blood that contains plasma (90%) and Proteins (10%).
Gibbs – Donnan Equilibrium	refers to movement of chargeable particles through a semipermeable membrane against its natural location to achieve equal concentrations on either side of the semi permeable membrane. For example, movement of Cl- from extracellular space (natural location) to intracellular space (unusual location) in case of hyperchloremic metabolic acidosis because negatively charged proteins (natural location in intravascular space) are large molecules that cannot cross the semipermeable membrane for this equilibrium.
Tonicity	of a solution means effective osmolality in relation to plasma (=285 milliosmol/L). Therefore, isotonic solutions [e.g. 0.9% saline solution] have almost equal tonicity of the plasma, hypotonic solutions [e.g. 0.45% saline solution] have < tonicity than plasma, and hypertonic [e.g. 3% saline solution] solutions have > tonicity than plasma.