

Principles of fluid and electrolyte balance in surgical patients

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Objectives:

- Identify types of intravenous fluids
- Revision of fluid compartments (physiology part) (fluid & substance)
- Prescribing fluids
- Electrolytes abnormalities
- Acid-base balance

Color Index:

-Doctor's Notes -Surgery Recall -Doctor's Slides+433 team -Important
-Extra (in this lect Davidson's notes are included)

● Why is it important?

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



● Theory part:

Definition:

- Intravenous (IV) fluids are infused (through a vein)
- to maintain fluid balance,
- replace fluid losses, and
- treat 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,
- medications.

● IV fluids:



"crystal"loids



"call"oids

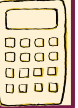
*Calculation of serum osmolality

- 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



	Crystalloid solutions	Colloid solutions
Contents	<ul style="list-style-type: none"> ● water + electrolytes (e.g.,sodium, potassium, calcium, chloride) ● Lack the large proteins and molecules ● Come in many preparations and volumes 	<p>Water + large proteins + molecules. Water and high molecular weight substances..</p> <p>Ex: Albumin, Polysaccharides (Dextran, hetastarch)</p>
Characteristics	<ul style="list-style-type: none"> ● Classified according to their "tonicity comparing to plasma*": <ul style="list-style-type: none"> ➤ Isotonic: 0.9% NaCl (normal saline), Lactated Ringer's solution ➤ Hypotonic: 2.5% dextrose ➤ Hypertonic: 5% dextrose with 0.9% NaC ● When administered: The water take a tour across the 3 fluid compartments (ECF, ICF and interstitial) depending on the tonicity**... From HYPER to HYPO 	<ul style="list-style-type: none"> ● 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 :) ● Tend to stay within the vascular space and increase intravascular pressure <p>The intravascular half-life is usually between 6 and 24 hrs and such solutions are therefore appropriate for fluid resuscitation.</p>
Uses	<p>1-To correct electrolytes</p> <p>2-To maintain the fluid resuscitation</p>	<p>1-Only For temporary fluid resuscitation.and for deficit, Ex.Hypoalbuminemia⇒ simply give albumin Loss of blood⇒ simply give blood</p>
SE	Less	More, coagulopathy, reticuloendothelial system dysfunction, pruritis and anaphylactic reactions. HES in particular appears associated with a risk of renal failure when used for resuscitation in patients with septic shock.

*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).

Penetrating molecules: can diffuse through the cell membrane, causing momentary changes in cell volume as the solutes "pull" water molecules with them.⇒ See terminologies page for further understanding..



MEMORIZE THIS TABLE!

Mole vs Osm: Mole= number of molecules اشمل , Osm= number of osmotic (penetrating) molecules.

Ex. each mole of NaCl is osmotically active (will contribute in pulling water) fortunately NaCl is like our cooperative batch :))

300 mmol of NaCl=300 Osm, in other non cooprtive substance the osm is less than the moles.

Type of Fluid*	Sodium mmol/L	Potassium mmol/L	Chloride mmol/L	Osmolarity mmom/L	Weight average mol wtkd	Plasma volume expansion duration hrs+
plasma	136 - 145	3.5 - 5.0	98 - 105	280 - 300	-	-
5% Dextrose	0	0	0	278	-	-
Dextrose 0.18% saline	30	0	30	283	-	-
0.9% "normal" saline	154	0	154	308	-	0.2
0.45% "half normal" saline	77	0	77	154	-	-
Ringer's lactate	130	4	109	273	-	0.2
Hartmann's	131	5	111	275	-	0.2
Gelatine 4%	145	0	145	290	30,000	1-2
5% albumin	150	0	150	300	68,000	2-4
20% albumin	-	-	-	-	68,000	2-4
Hes 6% 130/0.4	154	0	154	308	130,000	4-8
Hes 10% 200/0.5	154	0	154	308	200,000	6-12
Hes 6% 450/0.6	154	0	154	308	450,000	24-36

Davidson's is considering Hartmann's and Ringer lactate as one solution b/c they almost have equal concentrations.. Just in case you were ask in the exam..

Squares = mentioned by davidson's, BUT please memorize it **ALL!!**



TAKE THE CHALLENGE

If you're done memorizing the table.. Try this quiz and see if you can beat my score 🐱

Normal saline fluid (NS 0.9%)

- (NS) – is the commonly-used term for a solution of 0.90% weight/volume (w/v) of NaCl, W/V= 9 grams /L, about 300 mOsm/L or 9.0 g per liter.

-As mentioned previously, mmol is used to calculate the molecules of salt rather than their weight in grams= 300 mol of NaCl⇒ (154 Na molecules+154 molecules of cl)

NOW, as all NaCl moles are active osmole, 300 mol=300 Osm

-So, from where the 0.9% came?? $9/1000 \Rightarrow 0.009 \times 100 = 0.9\%$

- Na is 154 and only Cl 154
- No K, No others..**
- We can describe any fluid either in g, mmol and osm
- In $\frac{1}{2}$ NS⇒ 1L of water contains HALF of all Mol,Osm and g
- In $\frac{1}{4}$ Ns⇒ 1L of water contains Quarter of all Mol, Osm and g



1 liter of water

+
(9 g or 300mmol)
Of NaCl

=
0.9 Saline
Easy recipe :)

Hartmann's fluid

One litre of Hartmann's solution contains:

- 131 mEq of sodium ion = 131 mmol/L.
- 111 mEq of chloride ion = 111 mmol/L.
- 29 mEq of lactate = 29 mmol/L.
- 5 mEq of potassium ion = 5 mmol/L.
- 4 mEq of calcium ion = 2 mmol/L
- An equivalent is defined as the number of moles of a given ion in a solution multiplied by the valence of that ion.
- A certain amount of univalent ions provides the same amount of equivalents while the same amount of divalent ions provides twice the amount of equivalents. For example, 1 mmol of Na^+ is equal 1 meq, while 1 mmol of Ca^{++} is equal 2 meq.



Heart
man?

● Physiology part: Fluid compartments & substances

- We are approximately two-thirds water
- Total body water is 60% of body weight
- Influenced by **age, sex and lean body mass**

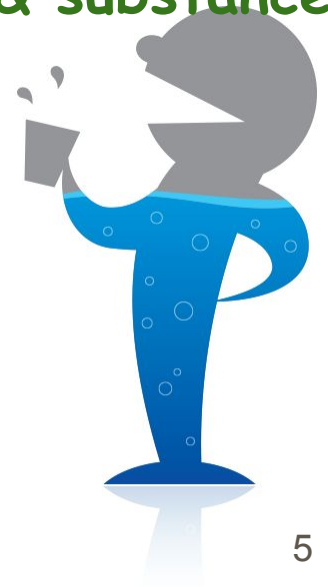
More fat⇒ less water

More muscles⇒ more water

- Older age and female sex is less present
- To calculate TBW needed:

Male sex TBW= BW× 0.6

Female sex TBW= BW × 0.5



Body fluid compartments:

- **Intracellular volume**
(40%) rich in water { (2/3rd=0.66) of total body water}
- **Extracellular volume**
(20%) rich in water { (1/3rd=0.33) of total body water}
15% constitute interstitial space and **5% the intravascular space**

Example: How much fluid is in your body?

- 70 kg male:
- $TBW = 70 \times 0.6 = 42 \text{ L}$

Fluid Compartments:

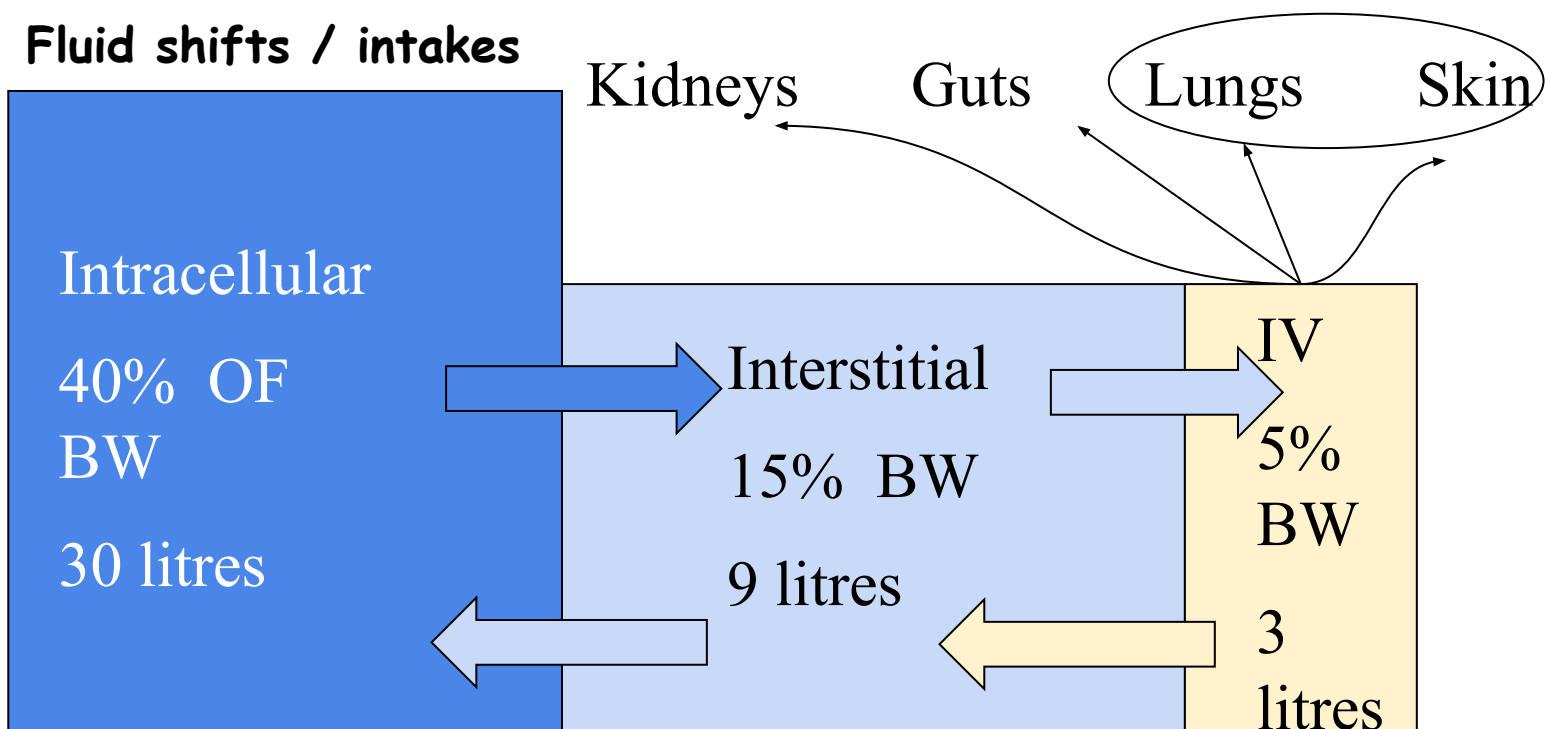
- Intracellular volume = $.66 \times 42 = 28 \text{ L}$ ($\frac{2}{3}$ of TBW= 66% = 0.66)
- Extracellular volume = $.34 \times 42 = 14 \text{ L}$ ($\frac{1}{3}$ of TBW= 34% = 0.34)
- Interstitial volume = $.66 \times 14 = 9.24 \text{ L}$ ($\frac{2}{3}$ of ECF)
- Intravascular volume = $.34 \times 14 = 4.76 \text{ L}$ ($\frac{1}{3}$ of ECF)

FOCUS, it's content not daily requirement(in page 8)

TBW it's the whole water inside you and we عصرناه out, While the requirements is basicly what comes in = what comes out(urine, sweat..)

Ex. IMAGINE that you have 1 milion in your bank account :) , You took 100 and used it, now your daily requirements is to add 100 to your account, so you'll stay in equilibrium

Fluid shifts / intakes



BW = Body Weight
Circle⇒ insensible but measurable

← Extracellular fluid - 12 L → 6

• Electrolytes

Body electrolytes compartments:

- Intracellular volume

K⁺, **Mg⁺**, and **Phosphate (HPO₄⁻)**

(yes, there are sodium and other electrolytes intracellularly, but we're talking about the abundant ones)

- Extracellular volume

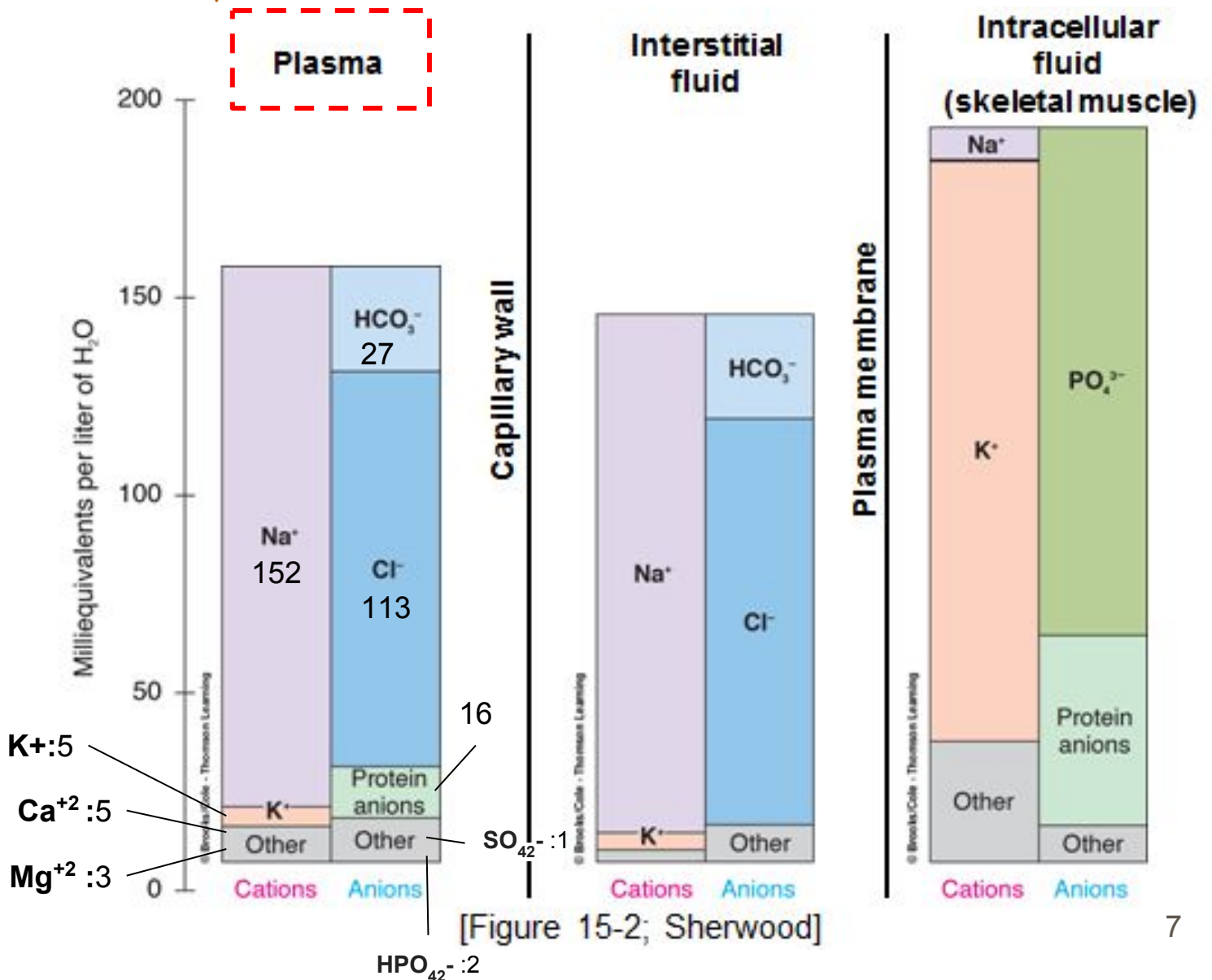
Na⁺, **Cl⁻**, **Ca⁺⁺**, and Albumin

Normal values of electrolytes: From davidson's

(Dr. Fahad said focus on the plasma only)

Intracellularly: Main cation=K and mg, Anion=PO4 and sulphate

Extracellularly: Main Cation=Na, Anion=Cl and HCO3



• Daily requirements of fluid and electrolytes:

• Fluid requirements:

We measure it for a fasting patient (NPO= nil per os, or nothing by mouth)

Remember: requirements is basically what comes in = what comes out (urine, sweat, stools, breathing...)

You can calculate it either by: body weight (the easier way)

Or by adding the losses and adding the gains and subtracted them from each other..

B/c we don't have time to calculate the amount of water in your sweat :), so they calculated two formulas based on your Body weight..

- **Normal adult requires approximately 35cc/kg/d** cc⇒ stands for "cubic centimeter"

For each kg, we need 35 cc.(In normal condition, person who loses 1.5 L in urine)

However if your patient is losing 10 L daily⇒ multiply the value by 10

Eg. if the BW =70kg

1. fluid required daily is: $35 \times 70 = 2450\text{cc/day}$
2. Fluid required **per hour**: $2450 \div 24 = 102\text{cc/hr}$

- **"4,2,1" Rule ml/hr:** Both will give almost the same result, However 4,2,1 is better..

First 10 kg= 4cc/kg/hr

Second 10 kg= 2cc/kg/hr

1cc/kg/hr

$$(10 \times 4) + (10 \times 2) + (\text{remainder BW} \times 1) = \text{ml/hr}$$

Now calculate it if the BW=70 kg⇒ 1st 10kg x4 , 2nd 10kg x2 , the remaining BWx1⇒ add the three results together=110 cc/hr

Both ways will give U an accurate number with small differences between the two (however rule 4,2,1 is better).



• Normal daily losses & requirements for fluids and electrolytes:

	Volume (ml)	Na+ (mmol)	K+ (mmol)
Urine	2000	80	60
Insensible losses* (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

***Insensible loss (eg. sweating) however it is measurable! Don't forget it!**

Fluid shifts in disease:

Fluid loss	Fluid gain
<ul style="list-style-type: none">● GI: diarrhoea, vomiting, etc.● Renal: diuresis● Vascular: haemorrhage● Skin: burns	<ul style="list-style-type: none">● Iatrogenic● Heart / liver / kidney failure

What is the IV fluid rate? Attention!!: in the prev page we calculated the fluid requirement (either per day or per hr) BUT in calculating the rate it must be (per hr)

In adults remember:

$$\text{IVF rate} = \text{Weight (kg)} + 40$$

(70 + 40 = 110cc/hr)

Or "4,2,1" Rule / hr (remember this rule give us the results per hr)

- Assumes no significant renal or cardiac disease and NPO (NPO = nothing by mouth)
- This is the maintenance IVF rate, it must be adjusted for any dehydration or ongoing fluid loss.

Sodium requirement:

- 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..

- Example: 70 kg male Na in 2600 cc not per L (110cc/hr × 24) fluid per day

- Now it's role to :

- 1st: calculate fluid requirement:

Using 4,2,1 rule = $(10 \times 4) + (10 \times 2) + (50 \times 1) = 110 \text{cc/hr} \Rightarrow \times 24 \text{ hr} = 2640 \Rightarrow$ the Na result is per day (**all units must be the same**)

- Do I need to calculate it always? yes , how can you make a recipe without knowing how much water you need to add :)
- 2nd: calculate the range of Na is needed: requires 70-210 meq

(to get the range multiply $\{70 \times (1-3) = 1 \times 70 - 3 \times 70\}$)

3rd: **decide which fluid is the best** according to L calculated in the 1st step (by multiplying the L of fluid by how much is the Na content)

- Ask the pharmacy to send 2,6 L of 0.45% saline contains 77 meq NaCl per liter ⇒ $77 \times 2.6 = 200.2 \text{ meq in } 2.6 \text{L}$ (200 meq which is exactly what we need here (70-210)).. Or give 1L of NS+ 1L of $\frac{1}{2}$ NS ⇒ 231 meq in 2 L almost what we need.. But, this way is too expensive and more complicated..

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

- Why not saline ⇒ saline contains 154 meq Na per L ⇒ if I gave 2.6 L for NPO patient ⇒ $154 \times 2.6 = 400.4 \text{ meq in } 2.6 \text{ L} > (77-210)$

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 osm 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.
- **Should not be administered at rate greater than 10-20 mmol/hr**

Ex in If I gave 1L (1000cc) of fluid containing 200 meq of K⇒then I've setted a rate of 100cc/hr is it Ok?? No, 1000cc of fluid⇒ 200 meq of K

Remove 1 zero from each side 100cc of fluid contains 20 meq of K⇒ cause thrombosis phlebitis in peripheral veins

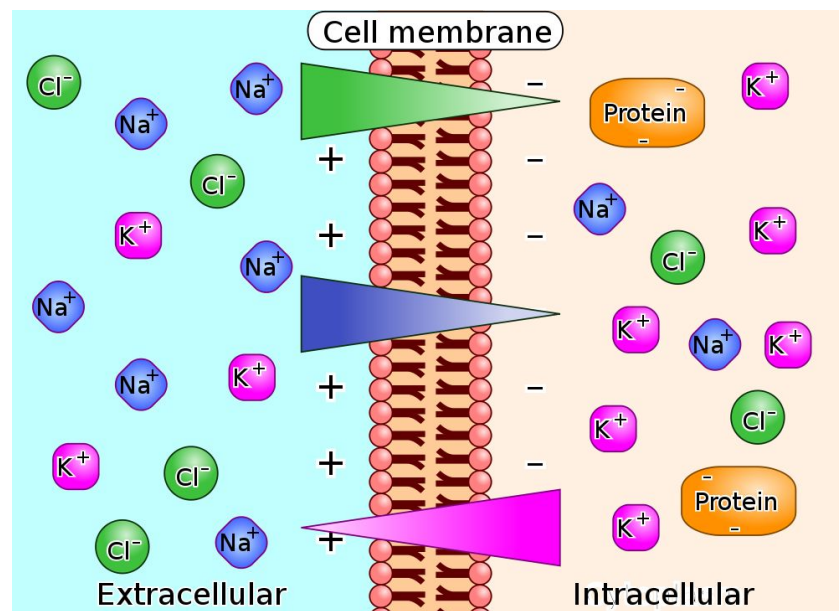
- It's fine to have higher rate if you infuse in central line(vien).



In some countries, large doses of potassium chloride injections are used as a way of punishment (when someone is sentenced to death) causing cardiac arrest.

For more details, read this [article](#), it's extremely interesting!!!

Osmotic/oncotic pressure, Gibbs-Donnan Equilibrium:



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.

● Medicine:

Terminologies:

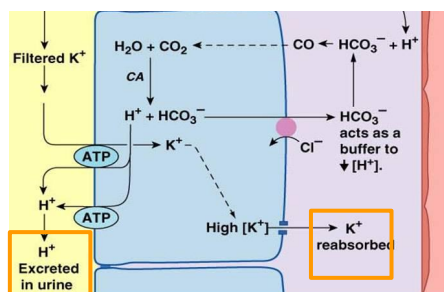
- **A solvent** is the liquid where particles dissolve in (e.g. Water) that can be measured in liters and milliliters
- **Solutes** are the dissolving particles
- **A molecule** is the smallest unit with chemical identity (e.g. Water consists of one oxygen and two hydrogen atoms = water molecule)
- **Ions** are dissociated molecules 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⁻) and **anions** are negatively charged ions (e.g. Cl⁻) due to gain of an electron (e⁻)
- **Electrolytes** are interacting cations and anions (e.g. H⁺ + Cl⁻ = HCl [hydrochloric acid])
- **A 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. H₂ [2 atoms] + O₂ [16 atoms] = H₂O [18 atoms])
- **A 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 × 10⁻³/L, micromoles × 10⁻⁶/L of the solvent.

Terminologies:

- **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%).
- **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.

1) Potassium

	Hypokalaemia (MOST COMMON)	Hyperkalemia(arrhythmias presentations)
Diagnosis	- Occurs when serum $K^+ < 3$ mEq/L.	- \uparrow serum $K^+ > 6$ meq/L and ECG changes.
Causes	<p>Reduced/inadequate intake Gastrointestinal tract losses</p> <ul style="list-style-type: none"> - Vomiting, Gastric aspiration/drainage, Fistulae, Diarrhoea, Ileus, Intestinal obstruction, and Potassium-secreting villous adenomas <p>Urinary losses</p> <ul style="list-style-type: none"> - Metabolic alkalosis, Hyperaldosteronism, Diuretic use, Renal tubular disorders(e.g. bartter's syndrome, renal tubular acidosis, amphotericin-induced tubular damage) 	<ul style="list-style-type: none"> - increase K^+ infusion in IVF, tissue injury, metabolic acidosis, renal failure, blood transfusion, and hemodialysis. - Haemolysis, Rhabdomyolysis, Massive tissue damage, and Acidosis.....ARF <p>(How come dialysis causes Hyper while it's used to correct it) We asked the dr about it, but still waiting for his answer..</p>
treatment	<ul style="list-style-type: none"> - Treatment involves KCl i.v. infusion or orally. - Should not be administered at rate greater than 10-20 mmol/hr 	<p>Treatment includes 1 ampule of D50% + 10 IU Insulin intravenously over 15 minutes, calcium oxalate enemas, Lasix 20-40 mg i.v., and dialysis if needed.</p> <ul style="list-style-type: none"> - Do ECG



2) Sodium

	Hyponatremia	Hypernatremia
Diagnosis	<135 mmol/L	Diagnosis is established when serum sodium > 145mEq/L.
Causes	<p>- Causes are hyperglycemia, excessive IV sodium-free fluid administration</p> <p>(Corrected Na= BS mg/dl × 0.016 + P (Na))</p> <p>explanation: this equation is used to differentiate between pseudohyponatremia(1) and Hyponatremia</p> <p>can be volum overload, normo, low</p> <p>- Hyponatremia with volume overload usually indicates impaired renal ability to excrete sodium</p> <p>Bs is blood sugar</p>	<p>- Reduced intake Of water Fasting</p> <p>- Increased loss of water Sweating, Burns</p> <p>- Inappropriate urinary water loss Diabetes insipidus (pituitary or nephrogenic), Diabetes mellitus, Excessive sodium load (hypertonic fluids, parenteral nutrition) .</p> <p>- this is primarily caused by high sodium infusion (e.g. 0.9% or 3% NaCl saline solutions).</p> <p>- Another but rare cause is hyperaldosteronism.</p> <p>- Patients with CHF, Cirrhosis, and nephrotic syndrome are prone to this complication</p> <p>- Symptoms and sign of are similar to water excess.</p>

In medicine and davidson's ⇒ CHF, cirrhosis and Nephrotic syndrome are under the hyponatremia, HOW come?
Still waiting for the dr answer :)

2) Sodium

	Hyponatremia	Hypernatremia
treatment	<ul style="list-style-type: none"> - Administering the calculated sodium needs in isotonic solution - In severe hyponatremia (Na less than 120meq/l): hypertonic sodium solution. - Rapid correction may cause permanent brain damage due to the osmotic demyelination syndrome - Serum Na should be increased at a rate that doesn't exceed 10-12meq/L/h. 	<ul style="list-style-type: none"> - Treatment include water intake and ↓ sodium infusion in IVF (e.g. 0.45% NaCl or D5%Water). Extra: (causes) - this is primarily caused by high sodium infusion (e.g. 0.9% or 3% NaCl saline solutions). - Another but rare 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.

Sodium Deficiency (Hyponatremia):

From (Davidson).

Hyponatremia can occur in the setting of decreased OR increased/normal ECF:

- Most common cause of increased ECF hyponatremia is excessive water administration (IV 5% dextrose) in the post-op period.
- Other causes: Secondary Hyperaldosteronism (cirrhosis, CHF), renal failure, TURP syndrome.
- Causes of decreased ECF hyponatremia include: diarrhea, diuretic use, adrenal insufficiency,
- Causes of normal ECF volume hyponatremia: SIADH, hypothyroidism.

Sodium Deficit equation:

$140 - \text{measured sodium} \times 0.2 \times \text{weight in Kg}$

Where 0.2 refers to 20% ECF.

Treatment depends on correcting the underlying cause

It's important to know how to differ between inappropriate ADH secretion from excessive water administration hyponatremia, and we can do that **by defining the urine osmolality**, in SIADH the urine will be concentrated.

In patients with decreased ECF volume hyponatremia, these patients usually have combined sodium and water deficiency and 0.9% NaCl should be administered.

The most serious clinical manifestation of hyponatremia is **metabolic encephalopathy** resulting in the shift of water into brain cells (from hypotonic environment to hypertonic environment) & cerebral edema occurs. Rapid correction of plasma Na concentration can precipitate an irreversible demyelinating condition known as central pontine myelinolysis. To avoid this, Na concentration should not increase by more than 0.5 mmol/hr.

3) Water Excess:

	Water Excess
Causes	inappropriate use of hypotonic solutions (e.g. D5%Water) leading to hypo-osmolar hyponatremia, and Syndrome of inappropriate anti-diuretic hormone secretion (SIADH)⁽¹⁾ . Diagnosis of SIADH secretion is established when urine sodium > 20 mEq/L when there is no renal failure, hypotension, and edema.
Symptoms	Symptoms of water excess develop slowly and if not recognized and treated promptly, they become evident by convulsions and coma due to cerebral edema
Signs of Volume overload	Hypertension, Tachycardia, Raised JVP / gallop rh, Oedema, Pleural effusions, Pulmonary oedema, Ascites, Organ failure.
Treatment	water restriction and infusion of isotonic or hypertonic saline solution. Treatment involves restriction of water intake (<1000 ml/day) and use of ADH- Antagonist (Demeclocycline 300-600 mg b.i.d).

The role of ADH:

- ADH is secreted in response to **increase** in **osmolarity**, and a **decrease** in **volume**.
- ADH acts on DCT / CD to **reabsorb water** via **V2 receptors** & **aquaporin 2**. It Acts only on WATER!.

(1) SIADH causes :malignant tumors, CNS diseases, pulmonary disorders, medications, and severe stress.

4) Water Deficit:

Water Deficit	
Diagnosis	Diagnosis can be confirmed by \uparrow serum sodium ($>145\text{mEq/L}$) and \uparrow serum osmolality ($>300\text{ mOsmol/L}$)
Causes	<p>the most encountered derangement of fluid balance in surgical patients.</p> <ul style="list-style-type: none"> - Causes include Bleeding, third spacing, gastrointestinal losses, increase insensible loss (normal $\approx 10\text{ml/kg/day}$), and increase renal losses (normal $\approx 500\text{-}1500\text{ ml/day}$).
symptoms	Symptoms of water deficit include feeling thirsty, dryness, lethargy, and confusion.
Signs 1)Volume depletion	<p>dry tongue and mucous membranes, sunken eyes, dry skin, loss of skin turgor, collapsed veins, depressed level of consciousness, and coma. Postural hypotension, Tachycardia, Absence of JVP @ 45°. Decreased skin turgor, Oliguria</p>
	<ul style="list-style-type: none"> - If sodium is $> 145\text{mEq/L}$ give 0.45% hypotonic saline solution, - if sodium is $>160\text{mEq/L}$ give D5%Water cautiously and slowly (e.g. 1 liter 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.

5) Calcium

	Hypocalcemia	Hypercalcemia
Diagnosis		Diagnosis is established by measuring the free Ca^{++} >10mg/dl.
Causes	Results from low parathyroid hormone after thyroid or parathyroid surgeries, low vitamin D, pseudohypocalcemia (low albumin and hyperventilation) . Other less common causes include pancreatitis, necrotizing fasciitis, high output G.I. fistula, and massive blood transfusion.	In surgical patients hypercalcemia is usually caused by hyperparathyroidism and malignancy.
symptoms	may include numbness and tingling sensation circumorally or at the fingers' tips. Tetany and seizures may occur at a very low calcium level. Signs include tremor, hyperreflexia, carpopedal spasms and positive Chvostek sign.	Symptoms of hypercalcemia may include confusion, weakness, lethargy, anorexia, vomiting, epigastric abdominal pain due to pancreatitis, and nephrogenic diabetes insipidus polyuria.
treatment	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.	Treatment includes normal saline infusion, and if CA^{++} >14mg/dl with ECG changes additional diuretics, calcitonin, and mithramycin might be necessary

6) Magnesium

	Hypomagnesaemia	Hypermagnesaemia
causes	<ul style="list-style-type: none"> - 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. - 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. 	<ul style="list-style-type: none"> - Mostly occur in association with renal failure, when Mg⁺ excretion is impaired. - The use of antacids containing Mg⁺ may aggravate hypermagnesaemia. - Treatment includes rehydration and renal dialysis.

7) phosphate

	Hypophosphatemia:	Hyperphosphataemia:
causes	<p>This condition may result from :</p> <ul style="list-style-type: none"> -inadequate intestinal absorption, -increased renal excretion, -hyperparathyroidism, - massive liver resection, and -inadequate replacement after recovery from significant starvation and catabolism. 	<p>Mostly is associated with renal failure and hypocalcaemia due to hypoparathyroidism, which reduces renal phosphate excretion.</p>
treatment	<ul style="list-style-type: none"> -Hypophosphatemia causes muscle weakness and inadequate tissue oxygenation due to reduced 2,3- diphosphoglycerate levels. - Early recognition and replacement will improve these symptoms. 	



PTH Effects on Kidney

- ↓the loss of Ca^{++} ions in the urine by **stimulating Ca^{++} reabsorption**
- **inhibits phosphate reabsorption**



- **stimulate production of $1,25(\text{OH})_2\text{D}$**

SUMMARY OF ABNORMALITIES

From Davidson.

Abnormality	Range	Causes	Treatment
Water depletion	A 1-2% decrease → sensation of thirst. 4-5% decrease → dehydration	-Inadequate intake - GI losses	Water intake
Water excess	-	Large amounts of IV 5 % dextrose	Restriction of fluids
Hypernatremia	>145 mmol/L	-Water loss (hypovolemic hypernatremia) - Sodium gain (hypervolemic hypernatremia)	Isotonic crystalloid followed by gradual administration of water OR another option is ½ normal or ¼ normal saline → gradual correction of hypernatremia
Hyponatremia	<135 mmol/L	-Administration of hypotonic IV fluid or excessive 5% dextrose is administered postop.	Treat underlying cause, -excessive water: water intake reduced. -ECF reduced: 0.9% NaCl.
Hyperkalemia	> 5.5 mmol/L	Exogenous K	-
Hypokalemia	<3 mmol/L	-Metabolic alkalosis -Diuresis Increased aldosterone	-Oral/ nasogastric K replacement -IV replacement shouldn't exceed 20 mmol/hr
Metabolic acidosis	pH < 7.36	-increased endogenous acid production: increased anion gap acidosis -Increased loss of HCO ₃ : normal anion gap acidosis	Restoring circulating blood volume & tissue perfusion
Metabolic alkalosis	pH > 7.44	Increased plasma HCO ₃ & decrease H ⁺ . -hypokalemia & hypochloremia	Fluid replacement Correction of hypokalemia & hypochloremia

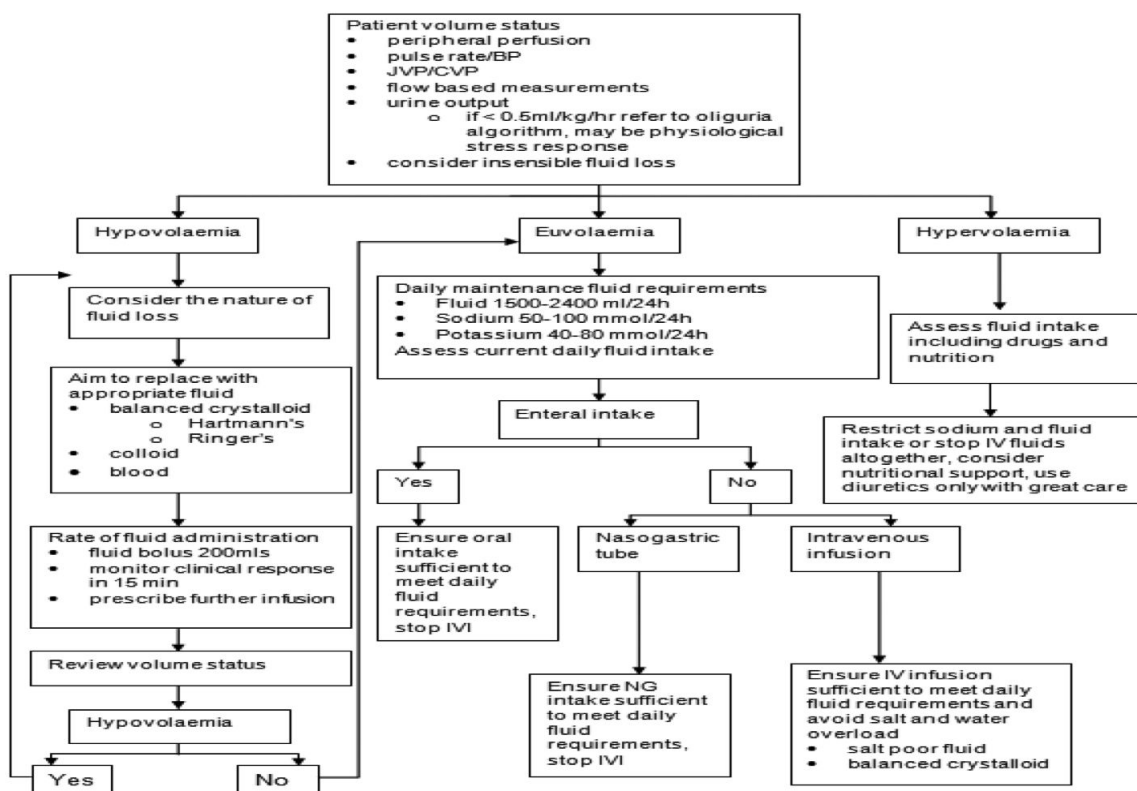
Prescribing fluids:

1) Crystalloids:(iso, hypo, hypertonic)	2) Colloids:
<ul style="list-style-type: none"> -0.9% saline - not " normal " -5% dextrose -0.18% saline + 0.45% dextrose -Others 	<ul style="list-style-type: none"> - blood - plasma / albumin - synthetics <p>Colloid solutions contain particles that exert an oncotic pressure and may occur naturally (e.g. albumin) or be synthetically modified (e.g. gelatins, hydroxyethyl starches [HES], dextrans).</p> <p>When administered, colloid remains largely within the intravascular space until the colloid particles are removed by the reticuloendothelial system. The intravascular half-life is usually between 6 and 24 hours and such solutions are therefore appropriate for fluid resuscitation. Thereafter, the electrolyte-containing solution distributes throughout the EFC.</p>

The rules of fluid replacement:

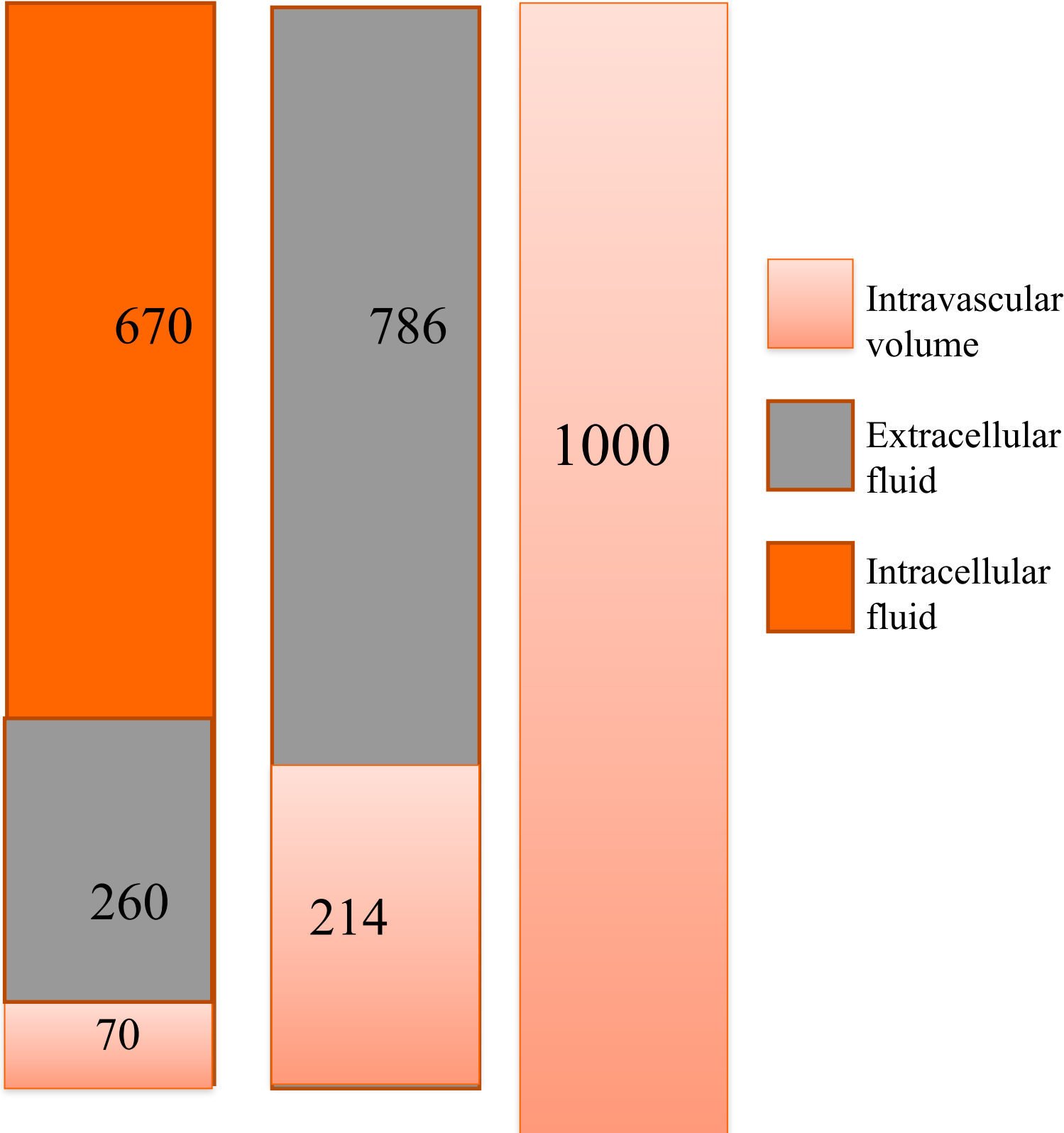
- Replace blood with blood
- Rehydrate with dextrose
- Replace plasma with colloid
- Replace ECF depletion with saline
- Resuscitation with colloid

Guidelines for fluid therapy



Principles of surgical care

see the next pages to know the mechanism



- 5% dextrose

- 0.9% NaCl
- ringer,s lactate
- Hartmann's solution

- 4.5% albumin
- Starches
- Gelofusine
- haemacel

NOTES FROM DAVIDSONS

- The distribution of fluid between the intra- and extravascular compartments is dependent upon the **oncotic pressure** of plasma and the **permeability** of the endothelium, both of which may alter following surgery as described above. Plasma oncotic pressure is primarily determined by **albumin**.

IN A WORD ⇒ WHEREVER ALBUMIN IS, FLUID WILL FOLLOW..

- The theoretical advantage of colloids over crystalloids is that, as they remain in the intravascular space for several hours, smaller volumes are required. However, overall, current evidence suggests that crystalloid and colloid are equally effective for the correction of hypovolemia
- insensible fluid losses
- Hyperventilation increases insensible water loss via the respiratory tract, but this increase is **not** usually large unless the normal mechanisms for humidifying inhaled air (the nasal passages and upper airways) are compromised. This occurs in intubated patients or in those receiving non humidified high-flow oxygen. In these situations inspired gases should be humidified routinely.
 - Pyrexia increases water loss from the skin by approximately **200ml/day for each 1°C rise in temperature**. Sweating may increase fluid loss by up to 1 litre/hour but these losses are difficult to quantify. Sweat also contains significant amounts of sodium (20-70 mmol/l) and potassium (10 mmol/l).
- When choosing and administering intravenous fluids, it is important to consider:
- what fluid deficiencies are present
 - the fluid compartments requiring replacement
 - any electrolyte disturbances present
 - which fluid is most appropriate.
- **Isotonic crystalloids** are appropriate for correcting EFC losses (e.g. gastrointestinal tract or sweating) and for the initial resuscitation of intravascular volume, although only about 25% remains in the intravascular space after **redistribution** (often less than 30-60 minutes).
- **Balanced solutions** such as Ringers lactate, closely match the composition of extracellular fluid by providing physiological concentrations of sodium and lactate in place of bicarbonate, which is unstable in solution.

After administration ⇒ the lactate is metabolised ⇒ resulting in bicarbonate generation.

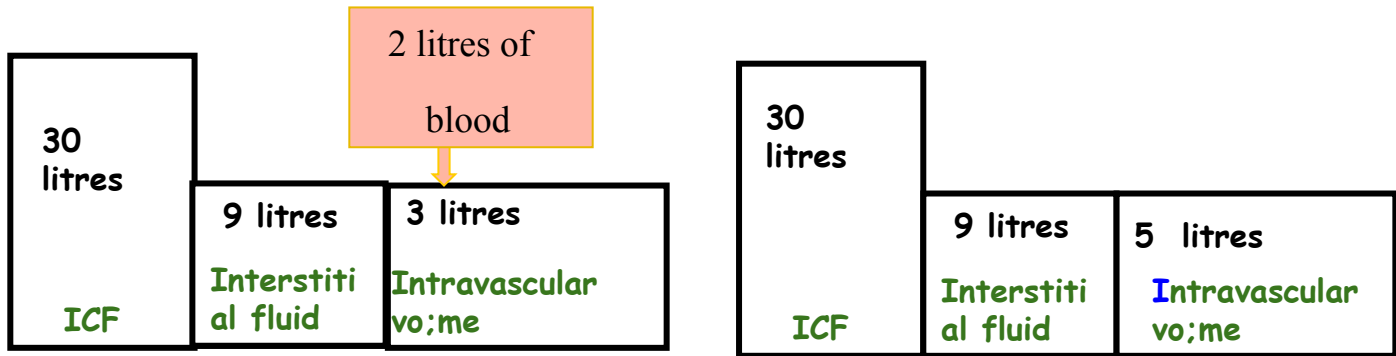
These solutions decrease the risk of hyperchloraemia, which can occur following large volumes of fluids with higher sodium and chloride concentrations.

Hyperchloremic acidosis can develop in these situations, which is associated with adverse patient outcomes and may cause renal impairment. Some colloid solutions are also produced with balanced electrolyte content.

- **Hypertonic saline solutions** induce a shift of fluid from the IFC to the EFC ⇒ so, reducing brain water and increasing intravascular volume and serum sodium concentration. ⇒ Potential indications include the treatment of cerebral oedema and raised intracranial pressure, hyponatremic seizures and 'small volume' resuscitation of hypovolaemic shock.

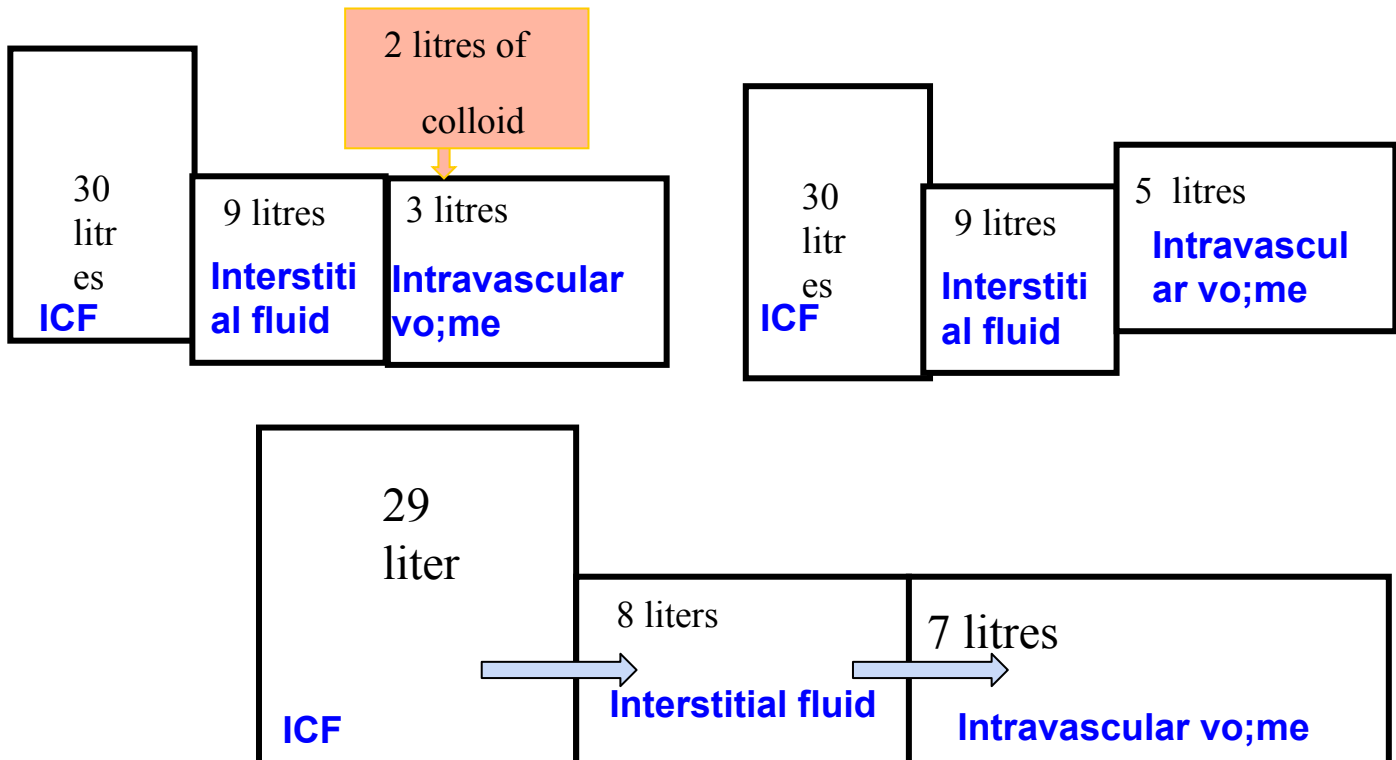
Crystalloids & colloids

1) 1st case



Giving 2 litres of blood to someone, will expand their intravascular compartment by 2 litres. None of this fluid will escape across the blood vessel walls (in the short term at least) and the other compartments are unaffected. This is the right treatment for blood loss.

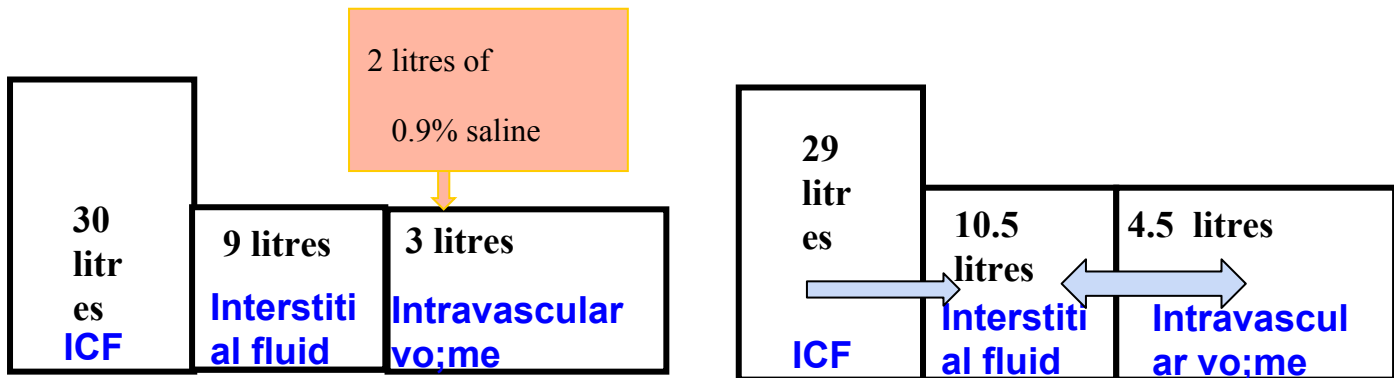
2) 2nd case



Colloid does not escape from the vascular space, but does increase oncotic pressure markedly ...

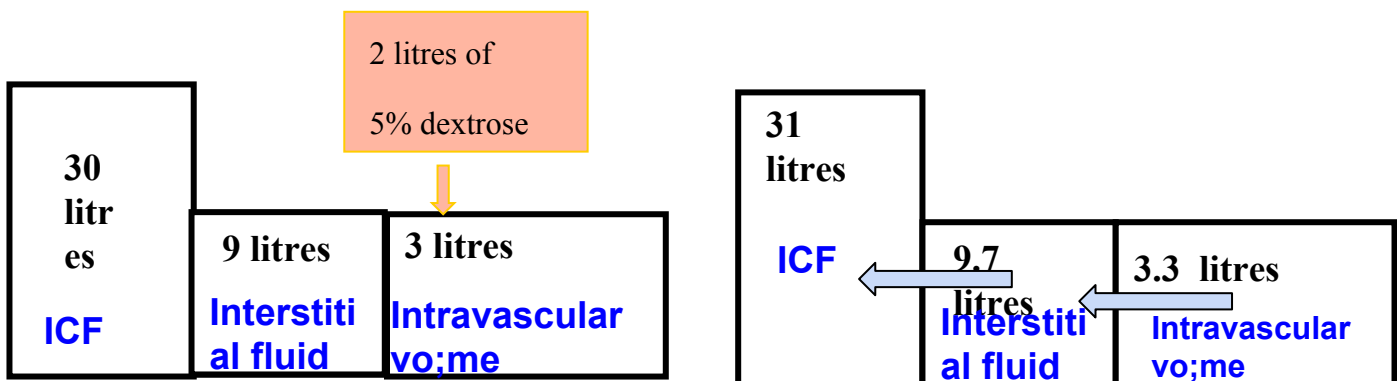
Crystalloids & colloids

3) 3rd case



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 \Rightarrow Saline will therefore cause immediate expansion of the intravascular volume, followed by \Rightarrow 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 equalise osmolality throughout all three compartments.

4) 4th case

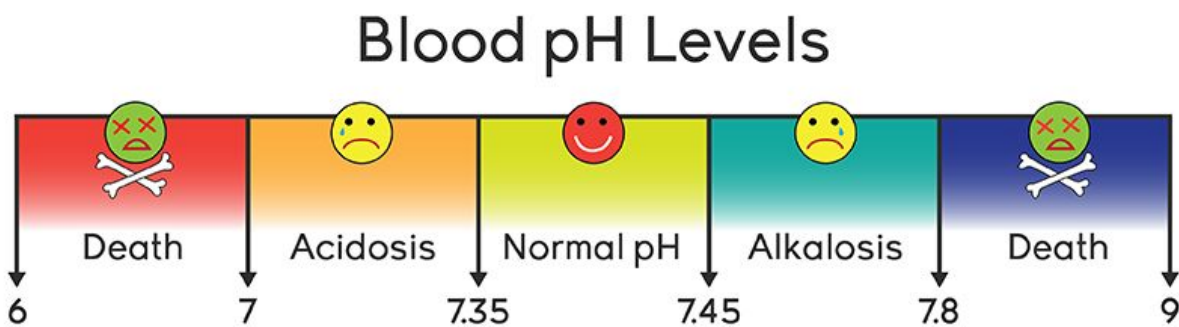


5 Dextrose is isotonic to plasma. Giving 2 litres of 5% dextrose will cause the immediate expansion of the vascular compartment \Rightarrow but, as its glucose content is rapidly metabolised, the remaining water will distribute itself between all compartments and very little will remain within the blood space. For this simple reason, dextrose is **not** a fluid of resuscitation.

● 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 CO₂ production
- It is mainly intracellular
- **PH depends on HCO₃ & CO₂**
- PH = log 1/[H⁺]
- Normal PH range = 7.3 - 7.42
- PH < 7.3 indicates acidosis
- PH > 7.42 indicates alkalosis



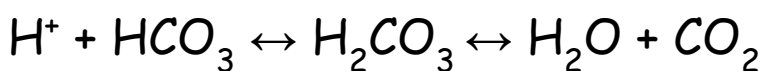
Buffers:

A buffer is an aqueous solution that resists changes in pH upon the addition of an acid or a base

1- Intracellular

- Proteins
- Hemoglobin
- Phosphate

2- bicarbonate/carbonic acid system



The main MECHANISM

How do you read A/VBG? important

pH	7.3-7.4
Partial pressure of CO ₂ in plasma (Pco ₂)	40 mmHg
Partial pressure of O ₂ in plasma (Po ₂)	65 mmHg
Bicarbonate concentration (HCO ₃)	24 mEq/L
O ₂ Saturation	≥ 90%
Base Excess	2.5 mEq/L <2.5 → metabolic acidosis >2.5 → metabolic alkalosis
Anion Gap (Na ⁺ - [HCO ₃ +Cl])	12 >12 → metabolic acidosis <12 → metabolic alkalosis

Anion Gap:

AG= Cations - Anions

- AG= Cations (Na⁺ + K) - Anions (Cl + HCO₃)
- Normal value is 12 mmol
- Metabolic acidosis with:

1-Normal AG (Renal tubular acidosis, Diarrhea ⇒ due to a loss of bicarbonate. This is compensated by an increase in chloride concentration, thus leading to a **normal anion gap**)

2-High AG

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

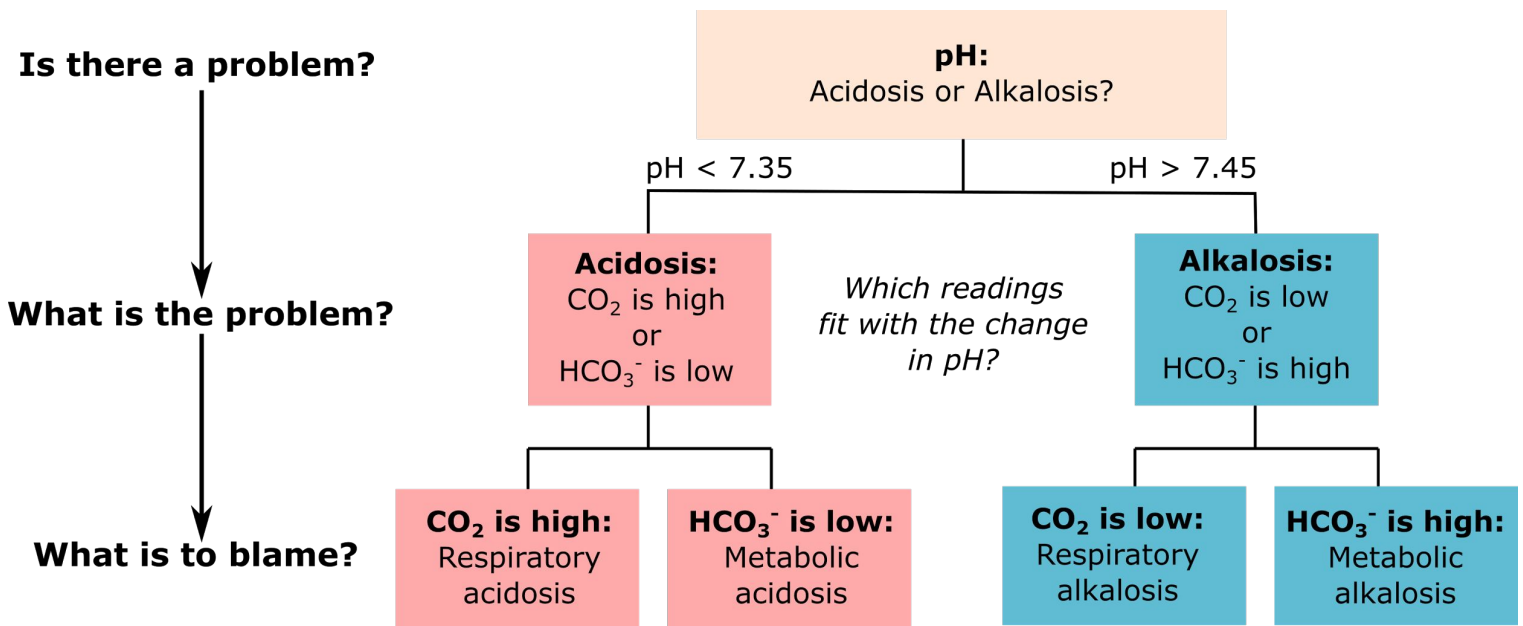
Causes of elevated Anion gap acidosis mnemonic: **MUDPILES!**

- M** = Methanol
- U** = Uremia
- D** = DKA (also AKA (Alcoholic Ketoacidosis) and starvation)
- P** = Paraldehyde
- I** = INH (Isoniazid)
- L** = Lactic acidosis
- E** = Ethylene Glycol
- S** = Salicylate



● Acid-Base disorders:

Metabolic Acidosis	Respiratory Acidosis
<p>Lactic acidosis</p> <ul style="list-style-type: none"> ● Shock (any cause) ● Severe hypoxaemia ● Severe haemorrhage/anaemia ● Liver failure <p>Accumulation of other acids</p> <ul style="list-style-type: none"> ● Diabetic ketoacidosis ● Acute or chronic renal failure ● Poisoning (ethylene glycol, methanol, salicylates) <p>Increased bicarbonate loss</p> <ul style="list-style-type: none"> ● Diarrhoea ● Intestinal fistulae 	<p>Common surgical causes of respiratory acidosis</p> <p>Central respiratory depression</p> <ul style="list-style-type: none"> ● Opioid drugs ● Head injury or intracranial pathology <p>Pulmonary disease</p> <ul style="list-style-type: none"> ● Severe asthma ● COPD ● Severe chest infection
Metabolic Alkalosis	Respiratory Alkalosis
<ul style="list-style-type: none"> ● Loss of sodium, chloride, water: vomiting, NGT, LASIX ● hypokalaemia 	<ul style="list-style-type: none"> ● Pain ● apprehension/hysterical hyperventilation ● Pneumonia ● Central nervous system disorders (meningitis, encephalopathy) ● Pulmonary embolism ● Septicaemia ● Salicylate poisoning ● Liver failure



Type of A-B disorder	Acute (Uncompensated)			Chronic (Partially compensated)		
	PH	PCO2	HCO3	PH	PCO2	HCO3
Respiratory acidosis	↓↓	↑↑	Normal	↓	↑↑	↑
Respiratory alkalosis	↑↑	↓↓	Normal	↑	↓↓	↓
Metabolic acidosis	↓↓	Normal	↓↓	↓	↓	↓
Metabolic alkalosis	↑↑	Normal	↑↑	↑	↑	↑

In order to assess how much fluid to give to someone, we need to know:

What is your starting point (hydration level)?

- Euvolemia? (normal)
- Hypovolemia? (dry)
- Hypervolaemia? (wet)

The aim of fluid administration is the maintenance of organ perfusion by keeping total body water at 55 - 60% - this is the **euvolemic state**.

Hypovolemia: 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.

What are the expected losses?

- Measurable:
 - urine (measure hourly if necessary)
 - GI (stool, stoma, drains, tubes)
- Insensible:
 - sweat
 - exhaled



Any fluid lost from the body is potentially in need of replacement, be it urine, stool, or fluid from drains, or other tubes.

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 expected gains?

- | | |
|---------------------------|---------------------------|
| ● Oral intake: | ● IV intake: |
| ● fluids | ● colloids & crystalloids |
| ● nutritional supplements | ● feeds |
| ● bowel preparations | ● drugs |

Remember that a large amount of food is broken down, or melts into water, so this may need to be counted as well

Case 1: A 62 year old man is 2 days post-colectomy. He is euvolemic, 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?

Ans1:

No weight is given so we use the other way (add all gains and add all losses then subtract them from each other)

Note: remember to do calculations all units MUST be the same

1. Be sure that you change all units to L or ml (but L is easier \Rightarrow it gives smaller numbers)

2. Start adding the gains:

Fluid input: 500 ml = 0.5 L

3. Start adding the losses:

Fluid loss/day:

- Urine: $63 \times 24\text{hr}$ to get it in days = 1512 ml/day = 1.5 L/day
- Insensible loss: not mentioned so we assume it's 500 ml (usually it's 500-700)

The patient loses 2L/day and gains 0.5L.

4. Subtract (step 2 and 3) from each other:

Net result: $2 - 0.5 = 1.5$

He therefore needs **1.5 litres** of fluid IV today.

Ans2:

As he is euvolemic, 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 hypotonicity.

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 ?

Ans1:

No weight is given so we use the other way (add all gains and add all losses then subtract them from each other)

Note: remember to do calculations all units **MUST** be the same

1. Be sure that you change all units to L or ml (but L is easier \Rightarrow it gives smaller numbers)

2. Start adding the gains:

Fluid input: 18 L/3days

3. Start adding the losses:

Fluid loss/3days:

- Urine: 26.5 L/3days
- Insensible loss: not mentioned so we assume it's 500 ml/day which is (1500ml) 1.5 L/3days

4. Subtract (step 2 and 3) from each other:

Net result: $(26.5 + 1.5) - 18 = 10$ L

This equals a deficit of **10 litres**, and it is not surprising that she appears to be hypovolaemic with hypotension and tachycardia

Ans2:

Assuming that she was euvolemic 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?

Ans1:

No weight is given so we use the other way (add all gains and add all losses then subtract them from each other)

Note: remember to do calculations all units **MUST** be the same

1. Be sure that you change all units to L or ml (but L is easier \Rightarrow it gives smaller numbers)

2. Start adding the gains:

Fluid input: 9 L/3days

3. Start adding the losses:

Fluid loss:3days:

- Urine: 6 L/3days
- Insensible loss: not mentioned so we assume it's 500 ml/day which is (1500ml) 1.5 L/3days

4. Subtract (step 2 and 3) from each other:

Net result: $9 - (6+1.5) = 1.5$ L

His total fluid excess is therefore around **1.5 litres**

Ans2:

Although he is not drinking, he is overloaded and his IV fluids should be stopped. After a day without IV fluids, he should be euvolemic, 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 40.8°C. His charts for the last 24 hours reveal:

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 ?

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

Ans1:

No weight is given so we use the other way (add all gains and add all losses then subtract them from each other)

Note: remember to do calculations all units **MUST** be the same

1. Be sure that you change all units to L or ml (but L is easier ⇒ it gives smaller numbers)

2. Start adding the gains:

Fluid input: Blood transfusion, IV crystalloid, oral fluids

$$700\text{ml} + 2.5\text{L} + 500\text{ml} = 3.7\text{L}$$

3. Start adding the losses:

Fluid loss:

- Urine output, Drain output, NG tube
- Insensible loss: higher than normal because of his fever, and will be about 800 ml (increase by 100 ml/day/degree centigrade)

$$2.7\text{L} + 0.5\text{L} + 1.5\text{L} + 0.8\text{L} = 5.5\text{L}$$

4. Subtract (step 2 and 3) from each other:

Net result: $5.5 - 3.7 = 1.8\text{L}$

Net result: $5.5 - 3.7 = 1.8\text{L} \times 4$ (we've calculated the last day only, we still have 4 days out of 5)

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.

Ans2: 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.

Surgical Recall

- On average, blood accounts for **7%** of ideal body weight in adults.
- **Physiologic response to hypovolemia:**
 - Sodium/H₂O retention via renin → aldosterone
 - water retention via ADH
 - vasoconstriction via angiotensin II and sympathetics
 - low urine output
 - tachycardia (early), hypotension (late)
- **Third spacing:** Fluid accumulation in the interstitium of tissues, as in edema, eg., loss of fluid into the interstitium and lumen of a paralytic bowel following surgery.
- **Third spacing treatment:** IV hydration with isotonic fluids
- **Classic signs of third spacing:**
 - Tachycardia
 - Decreased urine output
- **Third spaced fluid tends to mobilize back into the intravascular space around postoperative day #3**
(Note: beware of fluid overload once the fluid begins to return to the intravascular space); switch to hypotonic fluid and decrease IV rate
- **Classic acid-base finding with significant vomiting or NGT suctioning:**
Hypokalemic hypochloremic metabolic alkalosis
- **Hypokalemia with NGT suctioning cause:** Loss in gastric fluid-loss of HCl causes alkalosis, driving K⁺ into cells
- **Why should sugar (dextrose) be added to maintenance fluid?** To inhibit muscle breakdown
- **Most common fluid used for trauma resuscitation:** LR
- **What IVF is used to replace duodenal or pancreatic fluid loss?** LR (bicarbonate loss)
- **What is a bolus?** Volume of fluid given IV rapidly (e.g., 1L over 1 hour); used for increasing intravascular volume, and isotonic fluids should be used (i.e., NS or LR). Dextrose shouldn't be combined with bolus fluids because it may lead to hyperglycemia

LR = Lactated Ringer's

Surgical Recall

What is the possible consequence of hyperglycemia in the patient with hypovolemia?
osmotic diuretics.

What is the most common cause of electrolyte abnormalities? Lab errors!

Hyperkalemia

What are the ECG findings? Peaked T waves, depressed ST segment, prolonged PR, wide QRS, bradycardia, ventricular fibrillation.

What are the critical value? $K^+ > 6,5$

What are the critical values? $K 6.5$

What is the urgent treatment?

IV calcium (cardioprotective), ECG monitoring, Sodium bicarbonate IV (alkalosis drives K intracellularly), Glucose and insulin, Albuterol, Sodium polystyrene sulfonate (Kayexalate) and furosemide (Lasix) and Dialysis.

What is the nonacute treatment?

Furosemide (Lasix), sodium polystyrene, and sulfonate (Kayexalate).

What is the acronym for the treatment of acute symptomatic hyperkalemia?

"CB DIAL K":

Calcium, Bicarbonate, Dialysis, Insulin/dextrose, Albuterol, Lasix, and Kayexalate

What is "pseudohyperkalemia"?

Spurious hyperkalemia as a result of falsely elevated K in sample from sample hemolysis.

Hypokalemia

What are the ECG findings? Flattening of T waves, U waves, ST segment depression, PAC, PVC, atrial fibrillation.

What is the maximum amount that can be given through a peripheral IV? 10mEq/hr

What is the most common electrolyte-mediated ileus in the surgical patient?

Hypokalemia

Surgical Recall

Hypokalemia

What electrolyte condition exacerbates digitalis toxicity? Hypokalemia

What electrolyte deficiency can actually cause hypokalemia? Low magnesium

What electrolyte must you replace first before replacing K? Magnesium

Why does hypomagnesemia make replacement of K with hypokalemia nearly impossible? Hypomagnesemia inhibits K reabsorption from the renal tubules

Hypernatremia

How fast should you lower the sodium level in hypernatremia? Guideline is 12 mEq/L per day

What is the major complication of lowering the sodium level too fast? Seizures due to cerebral edema (not central pontine myelinolysis).

Hyponatremia

What are the surgical causes of the following types and their treatment:

Hypovolemic

Diuretic excess, hypoaldosteronism, vomiting, NG suction, burns, pancreatitis, diaphoresis.

Rx: NS IV, correct underlying cause

Euvolemic

SIADH, CNS abnormalities, drugs.

Rx SIADH: furosemide and NS acutely, fluid restriction

Hypervolemic

Renal failure, CHF, liver failure (cirrhosis), iatrogenic fluid overload (dilutional).

Dilutional: fluid restriction and diuretics

How fast should you increase the sodium level in hyponatremia? Guideline is 12 mEq/L per day

What may occur if you correct hyponatremia too quickly? Central pontine myelinolysis!

What are the signs of central pontine myelinolysis?

1. Conclusion
2. Spastic quadriplegia
3. Horizontal gaze paralysis

What is the most common cause of mild postoperative hyponatremia? Fluid overload

How can the sodium level in SIADH be remembered? SIADH (Sodium Is Always Down Here) = Hyponatremia

Surgical Recall

"Pseudohyponatremia"

What is it? Spurious lab value of hyponatremia as a result of hyperglycemia, hyperlipidemia, or hyperproteinemia

Hypercalcemia

What are the causes? "CHIMPANZEES":

- Calcium supplementation IV
- Hyperparathyroidism (1 / 3)
- hyperthyroidism
- Immobility/Iatrogenic (thiazide diuretics)
- Mets/Milk alkali syndrome
- Paget's disease (bone)
- Addison's disease/Acromegaly
- Neoplasm (colon, lung, breast, prostate,
- multiple myeloma)
- Zollinger-Ellison syndrome (as part of MEN I)
- Excessive vitamin D
- Excessive vitamin A
- Sarcoid

What are the ECG findings? Short QT interval, prolonged PR interval

What are other options for lowering Ca level? Steroids, calcitonin, bisphosphonates (pamidronate, etc.), mithramycin, dialysis (last resort)

Hypocalcemia

How can the calcium level be determined with hypoalbuminemia? (4-measured albumin level) $3 - 0.8$, then add this value to the measured calcium level

What is Chvostek's sign? Facial muscle spasm with tapping of facial nerve (ink: CHvostek CHEek)

What is Trousseau's sign? Carpal spasm after occluding blood flow in forearm with blood pressure cuff

What are the signs/symptoms? Chvostek's and Trousseau's signs, perioral paraesthesia (early), increased deep tendon reflexes (late), confusion, abdominal cramps, laryngospasm, stridor, seizures, tetany, psychiatric abnormalities (e.g., paranoia, depression, hallucinations)

What are the ECG findings? Prolonged QT and ST interval (peaked T waves are also possible, as in hyperkalemia)

What is the acute treatment? Calcium gluconate IV

Surgical Recall

What is the chronic treatment? Calcium PO, vitamin D

What is the possible complication of infused calcium if the IV infiltrates? **Tissue necrosis**; never administer peripherally unless absolutely necessary (calcium gluconate is less toxic than calcium chloride during an infiltration).

What is the best way to check the calcium level in the ICU? Check ionized calcium

Hypermagnesemia

What is the surgical cause? TPN, renal failure, IV over supplementation

What are the signs/symptoms? Respiratory failure, CNS depression, decreased deep tendon reflexes

Hypomagnesemia

What is the other electrolyte abnormality that hypomagnesemia may make it impossible to correct?

Hypokalemia (always x hypomagnesemia with hypokalemia)

Hyperglycemia

What is the treatment? Insulin

What is the Weiss protocol? Sliding scale insulin

What is the goal glucose level in the ICU? 80-110 mg/dL

Hypoglycemia

What is the treatment? Glucose (IV or PO)

Hypophosphatemia

What is the complication of severe hypophosphatemia? Respiratory failure

What is the critical value? 1.0 mg/dL

What is the treatment? Supplement with sodium phosphate or potassium phosphate IV (depending on potassium level)

Hyperphosphatemia

What is the treatment? Aluminum hydroxide (binds phosphate)