432 Surgery Team

12 IV Fluids

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COLOR GUIDE: • Females' Notes • Males' Notes • Important • Additional

Objectives

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

Principles of fluid and electrolyte balance in surgical patients

Why it is important:

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

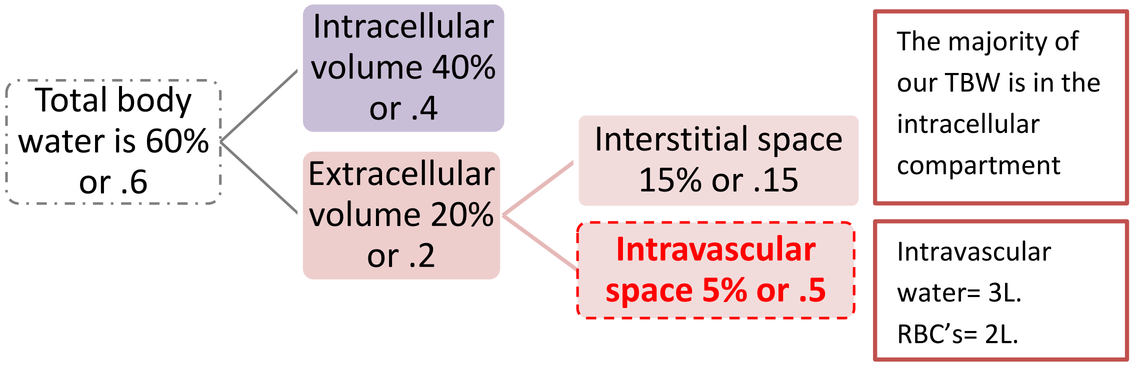
Introduction:

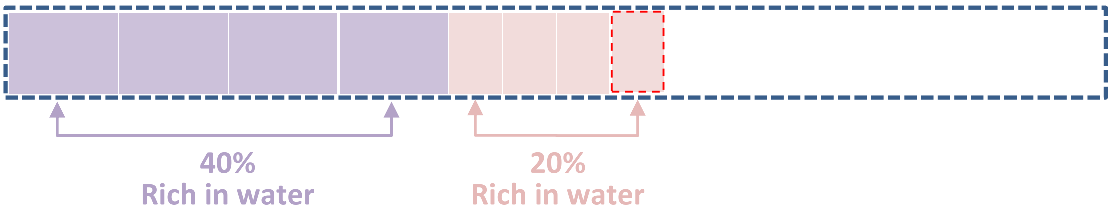
- **IV fluid** is the giving of **fluid and substances** *(electrolytes)* directly into a vein.
- Human Body has fluid and substances
- Substances that may be infused intravenously:
    - Volume expanders (crystalloids and colloids)
    - Blood-based products (whole blood, fresh frozen plasma, cryoprecipitate: a frozen blood product prepared from plasma)
    - Blood substitutes
    - Medications

Physiology:

- 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.
- 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.
- How to calculate **TBW** (Total body water)
    - Male TBW= BW x 0.6
    - Female TBW= BW x 0.

- # Body fluid compartments





TBW / BW = 60% or .6 → TBW = .6 × BW - you can calculate all the other values either by knowing TBW or BW choose one of them, memorize its equations, apply them and be an excellent student ;)

1. **Intracellular volume (ICV):**

$$\frac{ICV}{BW} = 40\% = .4\,(fixed\ value) \longrightarrow ICV = .4 \times BW$$

$$\frac{ICV}{TBW} = \frac{.4}{.6} = .66\,(fixed\ value) \longrightarrow ICV = .66 \times TBW$$

2. **Extracellular volume (ECV)**

$$\frac{ECV}{BW} = 20\% = .2\,(fixed\ value) \longrightarrow ECV = .2 \times BW$$

$$\frac{ECV}{TBW} = \frac{.2}{.6} = .33\,(fixed\ value) \longrightarrow ECV = .33 \times TBW$$

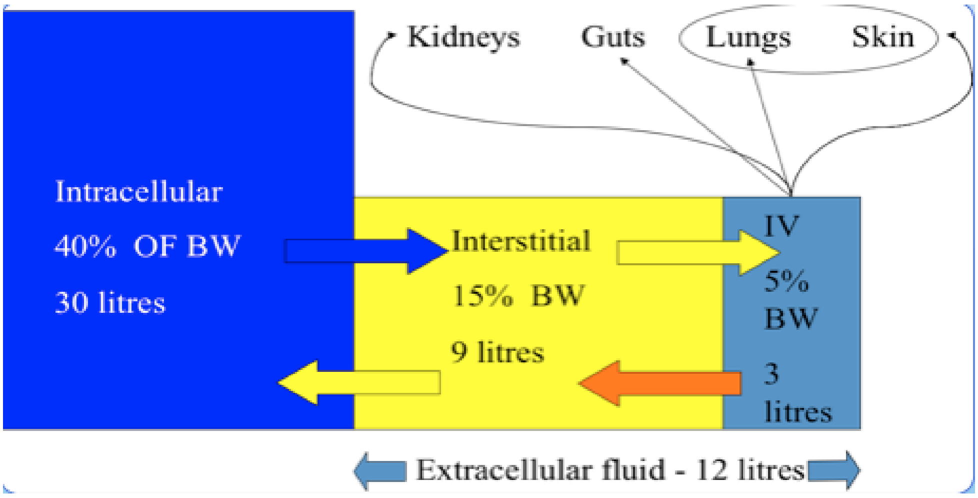
Take this example:

70 kg male (BW), his **TBW**= 70 × .6 = 42L (this equals 60% of his body weight)

1. ICV = 70 × .4 = 28L or ICV = 42 × .66 = 28L
2. ECV = 70 × .2 = 14L or ECV = 42 × .34 = 14L
3. Interstitial volume (ISV) = you can calculate it either by BW, TBW or ECV as long as you already figured it out =) it equals 15% or .15 of BW, 25% or .25 of TBW (15/60), 75% or .75 of ECV (15/20) in this case I'll calculate it using BW only = .15 × 70 = 10.5L. Same with Intravascular space (IVS) but you'll use 5% or .05 you can even calculate it this way: ECV – ISV = IVS → 14 – 10.5 = 3.5L

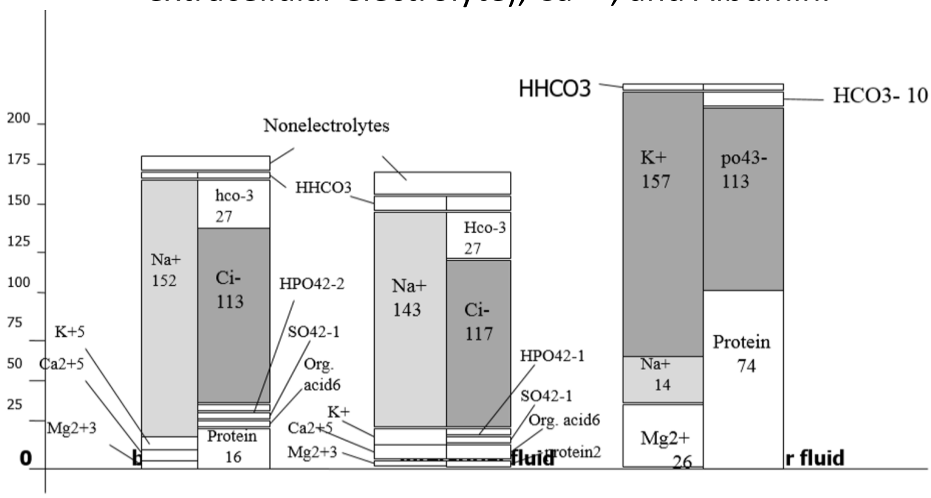
Fluid shift/intake

- Water moves **freely** between the compartments.
- We lose water through our **renal** and **gastrointestinal** tracts, and this can be seen and measured. The water we lose from our skin and respiratory tract can't be measured with ease, and makes up our insensible losses. It increases in sickness, particularly when febrile.



Body electrolytes compartments:

- Intracellular volume
    - K+ (the main +ve intracellular electrolyte), Mg+, and Phosphate (HPO_4^-) (the main –ve intracellular electrolyte).
- Extracellular volume
    - Na+ (the main +ve extracellular electrolyte), Cl-(the main –ve extracellular electrolyte), Ca++, and Albumin.



Normal electrolytes values:

Serum Na^+: 135 – 147 mmol/L

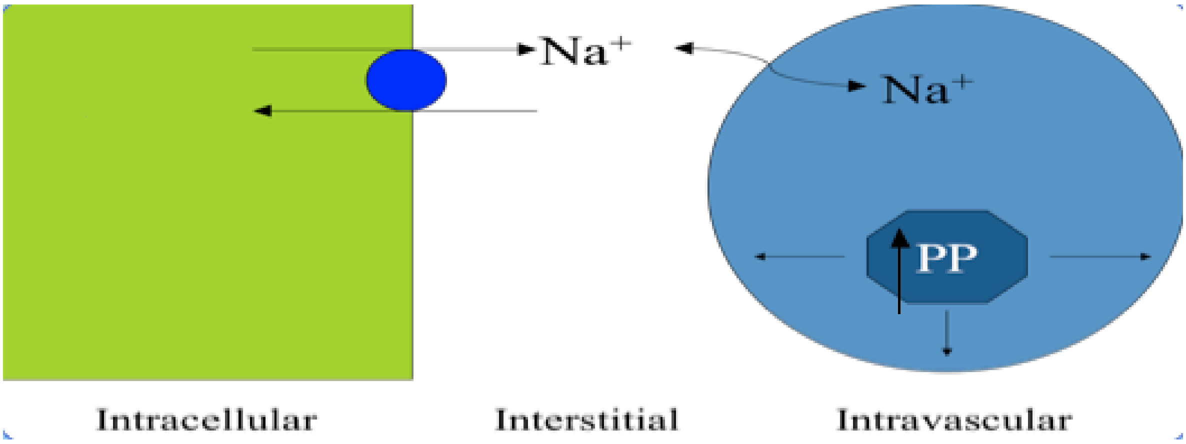
Serum K^+: 3.5 – 5 mmol/L

Serum CL^-: 98 – 108 mmol/L

Serum HCO_3: 20 – 28 mmol/L

Serum Ca^{+2}: 8.5 – 10.2 mg/dL (= 2.2- 2.6mmol/L)

- ## Osmotic/Oncotic pressure: **(understand this very well)**



> ***Note:***
>
> ***Gibbs – Donnan Equilibrium:*** *refers to movement of chargeable particles through a semi permeable membrane <u>against its natural location</u> 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 semi permeable membrane for this equilibrium.*

The distribution of water throughout the body depends on:

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

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

*It is also the cation that we most frequently administer by giving intravenous saline (NaCl). When we do this, **we increase extracellular tonicity** and water must move from the intracellular space to normalize osmolality.

How to measure osmolality of the blood?

Difficult: measure & add all active osmoles.

Easy = [sodium x 2] + urea + glucose.

* Conditions such as hypernatremia, renal failure (raised urea) or hyperglycemia, increase osmolality.

Because Na is the major extracellular cation.

Calculating osmoles let you know if the fluid is isotonic, hypo or hypertonic.

Types of IV fluids:

- **Colloid solutions**
  - Containing water and large proteins and molecules (high molecular weight).
  - **Don't contain electrolytes** (*not used for electrolytes imbalance)*
  - Tend to stay within vessels and increase intravascular pressure
  - Used for **volume expanding** (e.g. hypotension) and **protein replacement** only (e.g. low albumin)
  - Very expensive
    - *Examples: Dextran, hetastarch, albumin.*

- **Crystalloid solutions**
  - Contain water and varying concentrations of electrolytes (e.g. Na^+, K^+, Ca^{+2}, Cl)
  - **Don't contain proteins** nor large molecules (not effective in patient with hypoalbuminemia)
  - Come in many preparations and volumes
  - Classified according to their "**tonicity**":
  - Isotonic: equal tonicity to the plasma
    - **Normal saline**: is the commonly-used term for a solution of 0.9% weight/volume of **NaCl**, about **300** mOsm/L or 9.0 g per liter (1liter of normal saline contains **154 mmol/L of Na and 154 mmol/L of Cl** only) *remember the numbers for each subject*
    - **Lactated Ringer's solution**: 1 liter contains 130 mmol/L of Na, 109 mmol/L of Cl, 28 mmol/L of lactate, 4 mmol/L of K, 1.5 mmol/L of Ca.
    - **Hartmann's solution**: 1 liter contains 131 mmol/L of Na, 111 mmol/L of Cl, 29 mmol/L of lactate, 5 mmol/L of K, 2 mmol/L of Ca.
  - Hypotonic**:** have lesser tonicity than plasma, e.g. 2.5% dextrose.
  - Hypertonic**:** have greater tonicity than plasma, e.g. D5 NaCl.

Osmolality: dissolution of a solute in whole blood measured in kg.

Normal blood osmolality = 280-303 milliosmoles/kg

Tonicity of the crystalloids: effective osmolality in relation to plasma = 285 milliosmoles/L

Renger's lactate & hartmann's are very similar but not identical.
Renger's lactate is older.
Not used frequently due to its expensive price compared to normal saline.

Type of fluid*	Sodium (mmol/L)	Potassium	Chloride	Osmolarity
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***
0.45%"half normal" saline	***77***	***0***	***77***	***154***
Ringer's lactate	***130***	***4***	***109***	***273***
Hartmann's	***131***	***5***	***111***	**275**
Gelatin 4%	145	0	145	**290**
5% albumin	150	0	150	**300**
20% albumin	-	-	-	**-**
Hes 6% 130/0.4	154	0	154	**308**
Hes 10% 200/0.5	154	0	154	**308**
Hes 6% 450/0.6	154	0	154	**308**

Daily requirements of fluid

Normal adult requires **35 cc/kg/d** (multiply it by BW)

→ Normal requirement = BW **kg** × 35 = XXXX **cc/d**

Do not get confused:
1 mEq/L = 1 mmol/L
1 cc = 1 ml

Normal fluid output (loss):

Urine = 0.5-1 cc/kg/hr

Stool

Insensible (skin and respiratory tract) = 10 cc/kg/day (multiply it by BW to know the daily lost for each person)

- **Fluid shifts in disease:**
  - **Hypovolemia (fluid loss)**
    - GI: diarrhoea, vomiting, etc.
    - Renal: diuresis
    - Vascular: haemorrhage
    - Skin burns
  - **Hypervolemia (fluid gain)**
    - Heart/liver/kidney failure
    - Latrogenic

How to calculate fluid requirement {IVF maintenance}: *(very important)*

Fluid requirement = Normal requirement + Amount of lost fluid per day + Insensible loss.

This calculation for people who need IVF, who already lost fluid

For normal ones: daily fluid requirement = normal requirement

- Normal requirement cc/d = BW kg × 35
- Amount of lost fluid per day:
- You should know if the person has diarrhea or any disease to know how much fluid he has lost.
- Watch Input/output carefully and be aware of other losses
- Fever increases insensible loss by 200 cc/d for each degree.
- Monitor abnormal GI loss e.g. NGT suctioning (nasogastric tube).

	Volume (ml)	**Na+ (mmol)**	**K+ (mmol)**
Urine	2000	80	60
Insensible losses (skin and respiratory tract)	700	-	-
Faeces	300	-	10
Minus endogenous	300	-	-
Water	2700	80	70

- ### How to measure how much fluid should be given in an hour? *(2 rules)*

1. **Divide the daily fluid requirement by 24**
2. **"4, 2, 1" Rule:**
   - First 10 kg × 4 = 40 cc/hr
   - Second 10 kg × 2 = 20 cc/hr
   - for each additional 10 kg × 1 = 10 cc/hr

*Half normal saline (0.45%) will result in hyponatremia if given rapidly or in excess amount.
*Maintenance therapy should be tailored to the patient specific requirement.

Example: how much fluid does 100 kg male require?

Method 1: calculate the daily requirement and then divide it by 24

Normal requirement = BW kg × 35 = 3500 cc/d (=3.5 L/d)

3500 / 24 = 140 cc/hr

Method 2: 421 rule

1st 10 kg × 4 = 40

2nd 10 kg × 2 = 20

3rd 10 kg × 1 = 10, **4th** 10 kg 1 = 10 ………. **10th** 10 kg 1 = 10

→ 40 + 20 + 10 + 10 + 10 + 10 +10 +10 +10 +10 = 140 cc/hr

→ Instead of doing all these calculations, you might use this simple one: BW + 40 = IVF cc/hr

This assumes no significant renal or cardiac disease and NPO. *(Nil per os = Nothing by mouth)*
This is the maintenance IVF rate:

- It must be adjusted for any dehydration or ongoing fluid loss *(go check hypovolemic conditions)*
- Conversely, if the patient is taking some PO *(per os = by mouth)*, the IVF rate must be decreased accordingly.

Daily electrolytes, BUN, creatinine, Input/Output, and if possible, weight should be monitored in patients receiving significant IVF.

Electrolyte requirement:

Sodium requirement: Na: 1-3 mEq/**kg**/day → BW kg × 1-3 mEq/day

- 0.45% saline (half normal saline) contains 77 meq NaCl per liter.
- 0.45% saline is usually used as maintenance of IV fluid assuming no other volume or electrolyte issues.

Normal saline contain 154 meq/L of Na , half normal saline contain 77 meq/L of Na.
So, if a patient requires 300 meq of Na → give 2 normal saline, if require 70 meq of Na → give half normal saline.
Example: 70 kg male requires 70 - 210 mEq NaCl *(calculated by: BW × 1-3mEq)* in 2600cc =2.6L *(calculated by: BW × 35)* fluid per day.
In such case, you give the patient half normal saline. Why?

- The patient needs 70 – 210 mEq NaCl a **day**
- The half normal saline contains 77 mEq NaCl per **liter**, and the patient requires 2.6 **Liters** of fluid a day
- When measure it: 77 x 2.6 = 200 mEq a **day,** within the range 70-210
- Unlike giving normal saline which contains 154 mEq NaCl per liter (with 2.6 L, you will have 300 mEq NaCl! Which is out of the range 70-210)

Potassium requirement (K): 1 mEq/kg/day

- 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 patients who are NPO
- If significantly hypokalemia, order separate K supplementation
- Oral potassium supplementation is always preferred when feasible
- Potassium flow should not be exceed the rate 10-20 mmol/hr

The most important surgical abnormality is hypokalemia because they always give fluids but not k+

Rule of fluid replacement:

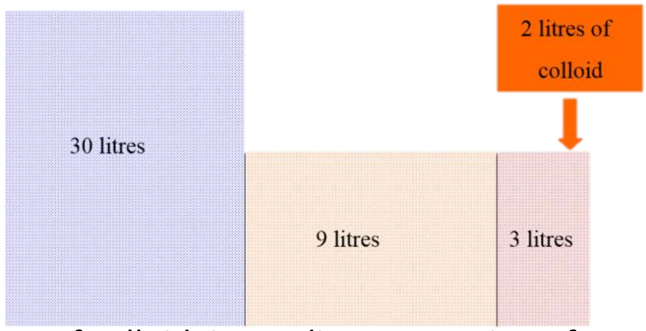
- Someone with serious intravascular volume depletion, hypotension and reduced cardiac output is shocked, whether it was caused by **blood** loss (e.g. Haemorrhage), **plasma** loss (e.g. Major burns), or **water** loss.
- The aim here is to restore intravascular volume with a fluid that remains in the 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** is 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 vascular space from interstitial and intracellular reservoir. Therefore, giving colloid not only expands the vascular space itself, but does so by moving water from other spaces into intravascular space.
- **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 equalise 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 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. For this simple reason, dextrose is not a fluid of resuscitation.

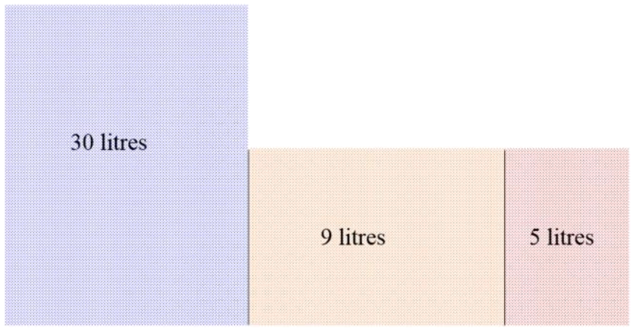
Summary:

- Replace blood with blood
- Replace plasma with colloid
- Replace ECF depletion with saline
- Dextrose should be given in case of dehydration
- The only thing that goes intracellular is the potassium

2L of Blood

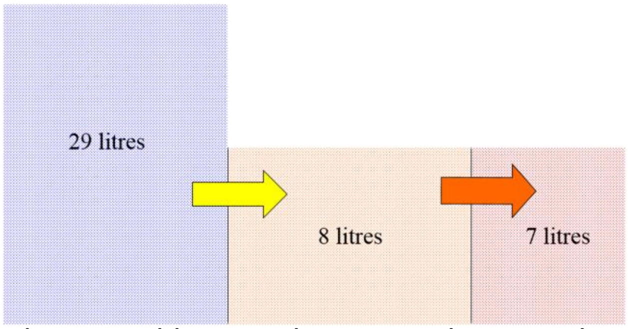


Stays in the intravascular compartment

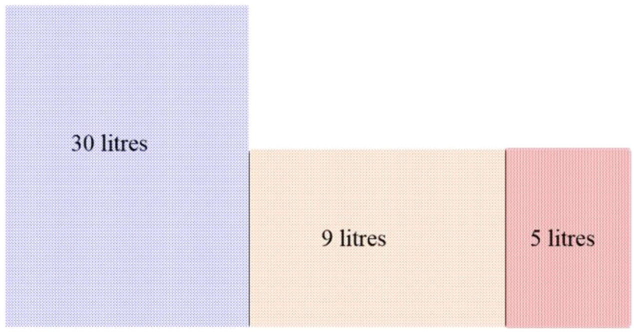


2L of colloid: immediate expansion of intravascular space and increases oncotic pressure

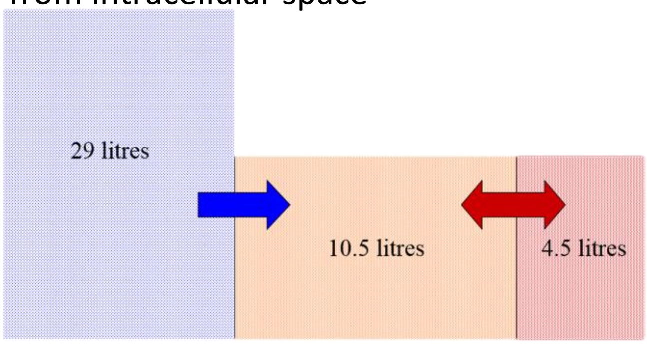
+ draws water from other compartments



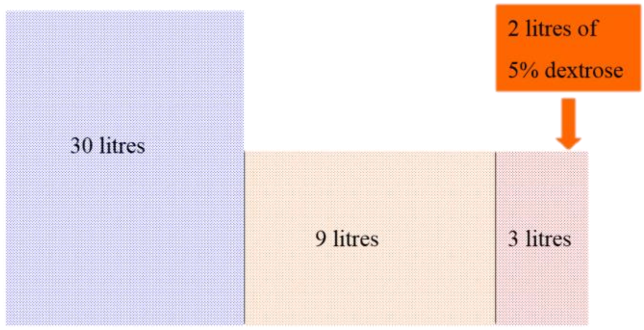
2L of crystalloid: immediate expansion of vascular compartment



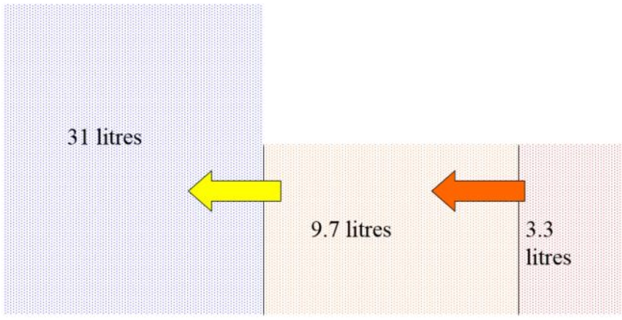
Then equilibration between the vascular and interstitial spaces and draws water from intracellular space



2L of 5% dextrose: immediate expansion of vascular compartment



Glucose content is rapidly metabolised. Remaining water will distribute itself between all compartments, little amount remain within blood space



Abnormalities:

Sodium:

Hypernatremia	Hyponatremia:
Diagnosis is established when serum sodium > 145mEq/L. **Causes:** • **High sodium infusion** (excessive normal saline 0.9% or hypertonic solutions e.g., 3% NaCl). • **Hyperaldosteronism** (rare – aldosterone promotes water and Na retention). • **Reduced water intake** by fasting, nausea and vomiting, ileus, reduced conscious level. • **Increased water loss** by Sweating (pyrexia, hot environment), Respiratory tract loss (increased ventilation, administration of dry gases) or burns. • Inappropriate **urinary water loss** by Diabetes insipidus (pituitary or nephrogenic), Diabetes mellitus. • Patients with **CHF**, **Cirrhosis**, and **nephrotic** syndrome are prone to this complication. **Signs and Symptoms:** very similar to water excess symptoms, includes coma, convulsions and confusion. **Treatment:** water restriction and ↓ sodium infusion in IVF (e.g. 0.45% NaCl or D5%Water).	**Causes:** • **Hyperglycemia** (it could be pseudohyponatremia: low serum sodium conc. Resulting from volume displacement by massive hyperlipidemia, hyperprotienemia or hyperglycemia e.g., diabetic). Corrected Na = BS mg/dl x 0.016 + P (Na)) (BS: blood sugar) • Excessive **IV sodium-free fluid** administration. • Hyponatremia with volume overload usually indicates impaired **renal** ability to excrete sodium **Treatment** • Administering the calculated sodium needs in isotonic solution. • In severe hyponatremia (Na <120meq/l): you give a hypertonic sodium solution. Rapid correction may cause permanent brain damage duo to the **osmotic demyelination syndrome. (Serum Na shouldn't be given at a rate > 10-12 meq/L/h)** Check first if it's a true hyponatremia or not by measuring albumin or glucose: If ↑ then it's pseudohyponatremia (treat by correcting glucose or protein levels only)

If a patient needs 600 Na and 3L of fluid? How will you manage him?
NS *(normal saline)* contain 154 → 154 × 2 = 308, 2%NS contain 308 → 308 × 2 = 616
2L of NS+1L of 2%NS= (2×154) +308=616 , fluid rate =weight+40=80+40=120cc/hr
Measure serum Na level every hour if ≥12mEq/L/hr, I have to correct either rate or Na concentration.

Potassium:

Hyperkalaemia	Hypokalaemia:
Diagnosis is established by serum K >6 meq/L and ECG changes. **Causes:** • Increase K+ infusion in IVF • Tissue injury, surgery. • Metabolic acidosis (increase H cause a shift of K from intracellular space into extracellular space). • Renal failure (↓excretion) • Blood transfusion • Hemodialysis. **Patient will present with Arrhythmia** **Treatment:** **1.** 1 ampule of D 50% + 10 IU Insulin intravenously over 15 mins. **2.** Calcium oxalate enemas (can also be given orally) **3.** Lasix 20-40 mg I.V. **4.** Dialysis if needed.	**Occurs when serum K+ <3 mEq/L.** • The most common surgical abnormality. **Causes:** • Reduced/inadequate intake • Gastrointestinal tract losses by vomiting, diarrhea, illeus, fistulae, gastric aspiration/drainage, intestinal obstruction, potassium-secreting villous adenomas • Urinary losses by metabolic alkalosis, hyperaldosteronism, diuretic use, renal tubular disorders (e.g. bartter's syndrome, renal tubular acidosis, amphotericin-induced tubular damage) **Symptoms:** weakness and fatigue (the most common), muscle cramps and pain (sever cases), altered level of consciousness, arrhythmia occurs in both hypo/hyperkalemia. **Treatment:** KCl i.v. infusion or orally. **Should not be administered at rate greater than 10-20 mmol/hr.**

Calcium:

Hypercalcemia	Hypocalcemia
• Diagnosis is established by measuring the free Ca^{++} >10mg/dl. • In surgical patients hypercalcemia is usually caused by ***hyperparathyroidism*** and malignancy. **Symptoms:** confusion, weakness, lethargy, anorexia, vomiting, epigastric abdominal pain (due to pancreatitis), and polyuria (due to nephrogenic diabetes insipidus). **Treatment:** normal saline infusion, and if CA^{++}>14mg/dl with ECG changes additional diuretics, calcitonin, and mithramycin might be necessary.	**Causes:** low parathyroid hormone (after thyroid or parathyroid surgeries), other less common **Other causes include:** • Low vitamin D • Pseudohypocalcemia (low albumin and hyperventilation). • Pancreatitis • Necrotizing fasciitis. • High output G.I. fistula. • Massive blood transfusion. **Symptoms:** • Numbness and tingling sensation circumorally or at the fingers' tips. • Tetany and seizures may occur at a very low calcium level. **Signs:** • tremor, hyperreflexia, carpopedal spasms and +ve Chvostek sign. **Diagnosis: serum Ca<8.5 mg/dl (2.1mmol/L)** **Treatment:** start with treating the cause. Calcium supplementation with calcium gluconate or calcium carbonate I.V. or orally. Vitamin D supplements especially in chronic cases.

Magnesium:

Hypermagnesaemia and hypophosphatemia are all conditions of renal failure.

Hypermagnesaemia	Hhypomagnesaemia:
• Mostly occur in association with renal failure, when Mg+ excretion is impaired. • The use of antacids containing Mg+ may aggravate Hypermagnesaemia. **Treatment:** Rehydration and renal dialysis.	• Usually there are **no symptoms** but when you want to correct Ca or K levels, they are not corrected. • Magnesium is important for neuromuscular activities.(cannot correct K nor Ca) • 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. • In surgical patients, hypomagnesaemia is a frequently missed common electrolyte abnormality, as **it causes no major alerting symptoms.** NPO long time → I have to give Mg

Phosphate:

Hyperphosphatemia	Hypophosphatemia
• Mostly is associated with renal failure and hypocalcaemia due to hypoparathyroidism, which reduces renal phosphate excretion.	**Causes:** • Decrease intestinal absorption • Increased renal excretion • Hyperparathyroidism. • Massive liver resection. • Inadequate replacement after recovery from significant starvation and catabolism. **Symptoms:** muscle weakness and inadequate tissue oxygenation due to reduced 2,3- diphosphoglycerate levels. ◦ Early recognition and replacement will improve these symptoms.

Mg and phosphate abmormalities occure with chornic diseases, before replacing them check the renal system, caused all the time be renal failure.

Water excess	Water deficit
Causes: • inappropriate use of hypotonic solutions (e.g. D5%Water) leading to hypo-osmolar hyponatremia. • Syndrome of inappropriate anti-diuretic hormone secretion (SIADH) ◦ Look for SIADH causes: malignant tumors, CNS diseases, pulmonary disorders, medications, and severe stress. **Symptoms:** develop slowly and if not recognized and treated promptly, they become evident by convulsions and coma due to cerebral edema **Signs:** Hypertension, Tachycardia, Raised JVP / gallop, edema, Pleural effusions, Pulmonary edema, Ascites, Organ failure. **Diagnosis: is established when urine sodium >20 mEq/L when there is no** renal failure, hypotension, **edema** **Treatment:** involves restriction of water intake (<1000 ml/day) and use of ADH- Antagonist (Demeclocycline 300-600 mg b.i.d).	**<u>the most encountered derangement of fluid balance in surgical patients</u>.** **Causes:** Bleeding, third spacing, gastrointestinal losses, increase insensible loss (normal ≈ 10ml/kg/day), and increase renal losses (normal ≈ 500-1500 ml/day). **Symptoms:** feeling thirsty, dryness, lethargy, and confusion. **Signs:** ◦ dry tongue and mucous membranes, sunken eyes, dry skin, loss of skin turgor, collapsed veins ◦ Postural hypotension, tachycardia, absence of JVP ◦ Oliguria, organ failure ◦ depressed level of consciousness, and coma **Diagnosis:** it can be confirmed by ↑ serum sodium (>145mEq/L) and ↑ serum osmolality (>300 mOsmol/L) **Treatment:** • If sodium is > 145mEq/L give 0.45% hypotonic saline solution, if sodium is >160mEq/L give D5% Water **cautiously and slowly** (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.

ADH = secreted in response to ↑osmolality or secreted in response to ⇓ volume

* ADH secretion is also influenced by volume receptors, so that hypovolaemia stimulates ADH secretion and water reabsorption. In the paradoxical situation where hypovolaemia is accompanied by a fall in osmolality, ADH secretion will increase - ie. the major stimulant is hypovolemia.

ADH acts on DCT / CD to reabsorb water
Acts via V2 receptors & aquaporin 2
Acts only on WATER
Anti-diuretic 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.
* It increases urine concentration.

Acid base balance:

- Hydrogen ion (mainly intracellular) is generated in the body by:

1. Protein and CHO metabolism (1meq/kg of body weight)
2. Predominant CO2 production

- PH depends on $\frac{HCO3}{CO2}$, PH = log 1/[H+]
- H+ conc. = 36 – 40 mmol/L

Normal PH range = 7.3 – 7.42

PH<7.3 indicates acidosis

PH>7.42 indicates alkalosis

The buffer system:

- **Mechanism to maintain pH normal Intracellular**
    a. Proteins: which include ***hemoglobin***, protein buffers include both basic and acidic buffers, that act as H+ depletors or donors to maintain pH level.

    b. Phosphate: when H concentration increases, it binds to H ions and is excreted in the urine with sodium.

- Mechanism to maintain pH normal value in ECF

The main mechanism to obtain normal value of pH intra/extracellular fluid

The buffer system: bicarbonate/carbonic acid system: pH level depend on CO2 & HCO3 mainly

Under the enzyme carbonic anhydrase

$H^+ + HCO_3 \leftrightarrow H_2CO_3 \leftrightarrow H_2O + CO_2$

Hydrogen ions and bicarbonate form carbonic acid, which forms CO_2 and water under the enzyme carbonic anhydrase

If H+ increases in plasma → CO_2 production increases → pH decrease (high acidity)

Respiratory compensation: in acidosis, pH changes stimulates respiratory center → hyperventilation → Pco_2 decrease → pH get back to normal

Metabolic compensation: high acidity → increase urinary excretion of acid + reabsorption of HCO3 → pH get back to normal

How to read arterial/venous blood gas:

If Pco_2 ↓ = metabolic,

↑ = respiratory.

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+K) – (HCO3+Cl) = 12 (>12 met. acidosis, < 12 met. alkalosis)

Acid base disorder:

Metabolic acidosis	Metabolic Alkalosis:
Low pH due to H+ accumulation and HCO3 ions decrease. **Causes:** **Normal Anion gap** (AG) (Diarrhea, Renal tubular acidosis, intestinal fistula). **High AG:** Lactic acidosis caused by shock (any cause), severe hypoxaemia, severe haemorrhage/anaemia, liver failure. Diabetic ketoacidosis Acute or chronic renal failure Poisoning (ethylene glycol, methanol,salicylates) Metabolic alkalosis Loss of H+ ions (vomiting, NGT, LASIX) Hypokalaemia HCO3 retention	High HCO3 => high pH **Causes:** ◦ H+ ions loss (vomiting, NGT, Lasix). ◦ Hypokalemia. ◦ HCO3 retention.

Respiratory acidosis	Respiratory Alkalosis:
Causes: (anything that causes hypoventilation) Common surgical causes of respiratory acidosis ◦ Central respiratory depression ◦ Opioid drugs ◦ Head injury or intracranial pathology ◦ Pulmonary disease ◦ Severe asthma ◦ COPD ◦ Severe chest infection ◦ Respiratory alkalosis	**Causes:** (anything that causes hyperventilation) ◦ Pain ◦ Apprehension/hysterical ◦ Pneumonia ◦ CNS disorders (meningitis, encephalopathy) ◦ hyperventilation ◦ Pulmonary embolism ◦ Liver failure ◦ Septicaemia ◦ Salicylate poisoning

Type of A-B disorder	Acute (uncompensated)			Chronic (partially compensated)		
	pH	Pco_2	HCO3	pH	Pco2	HCO3
Respiratory acidosis	↓↓	↑↑	Normal	↓	↑↑	↑
Respiratory alkalosis	↑↑	↓↓	Normal	↑	↓↓	↓
Metabolic acidosis	↓↓	Normal	↓↓	↓	↓	↓
Metabolic alkalosis	↑↑	Normal	↑↑	↑	↑	↑

SUMMARY

- K+ is the main +ve intracellular electrolyte
- Phosphate (HPO_4^-) is the main –ve intracellular electrolyte.
- Na+ is the main +ve extracellular electrolyte,
- Cl- is the main –ve extracellular electrolyte.
- Normal values: **pH = 7.36 – 7.4 / H+ concentration = 36 - 40 mmol/L / PaCO2 ~ 40 mmH / Bicarbonate concentration [HCO3-] = 20-28,**
- Fluid requirement = Normal requirement + Amount of lost fluid per day + Insensible loss.
- Normal adult requires approximately 35 cc/kg/d
- Sodium requirement : 1-3 meq/kg/day
- Potassium requirement: 1 meq/kg/day
- Normal saline contain 154 meq/L of Na , half normal saline contain 77 meq/L of Na.

Terminologies

- **A solvent** is the liquid where particles dissolves 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 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-) and **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])
- **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. H+ [2 atoms] + O_2 [16 atoms] = H_2O [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 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 semi permeable 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.

Questions

1) What is the composition of 0.9% Saline?

A) 130 mEq sodium, 109 mEq chloride, 28 mEq lactate.
B) 154 mEq sodium, 154 mEq chloride.
C) 513 mEq sodium, 513 mEq chloride.
D) 855 mEq sodium, 855 mEq chloride.

2) Which of the following is correct regarding the composition of the body fluid compartments?

A) The major intracellular cation is sodium.
B) The major intracellular anions are proteins and phosphates.
C) The major extracellular cation is potassium.
D) The major extracellular anion is magnesium.

3) Which one is the right equation to calculate fluid requirement?

A) Normal requirement + Amount of lost fluid per day + Insensible loss.
B) Amount of lost fluid per day + Insensible loss.
C) Normal requirement + Insensible loss.
D) Normal requirement + Amount of lost fluid per day

Answers:

1st Questions: B

2nd Questions: B

3rd Questions: A