MED437
KING SAUD UNIVERSITY

SURGERY TEAM 437

IV Fluid & Acid Base Disorder

Team leaders: Alanoud Almansour, Ghaida AL Musma , Moath Alhamoud and Mohammed Alquwayfili

Done by: Lama Al Musallam , Alfahdah Alsaleem , Mohammed Nouri & Khalid Alshehri

Revised by: Yazeed Al-Dossare

Color Index:

- Important
- Doctor's Notes
- Extra
- Davidson's

Editing File / Feedback

Objectives:

1. Review basics of fluid & electrolytes physiology in surgical patient
2. Be familiar with different types of commonly used IV fluids
3. Be able to calculate fluid & electrolytes requirement for a patient and choose the appropriate type of fluid
4. Understand different types of electrolytes and fluid disturbance and its management
5. Understand basics of acid-base physiology and common disorders

Principles of Fluid & Electrolytes

- **What is Intravenous fluid?**

★ Intravenous (IV) fluids is the giving of fluid and substances directly into a vein. They are
★ infused to maintain fluid balance, replace fluid losses, and treat electrolyte imbalances.
★ Have no Calories
★ If we give water Intravenously it will cause hemolysis
★ What will happen if we give a patient IV fluid for a whole one year?
  - They will die because they're not getting enough nutrition since IV fluids have no calories thus the body will start consuming its glycogen, protein and fat stores and then they will slowly collapse and die, however their body will be well hydrated.

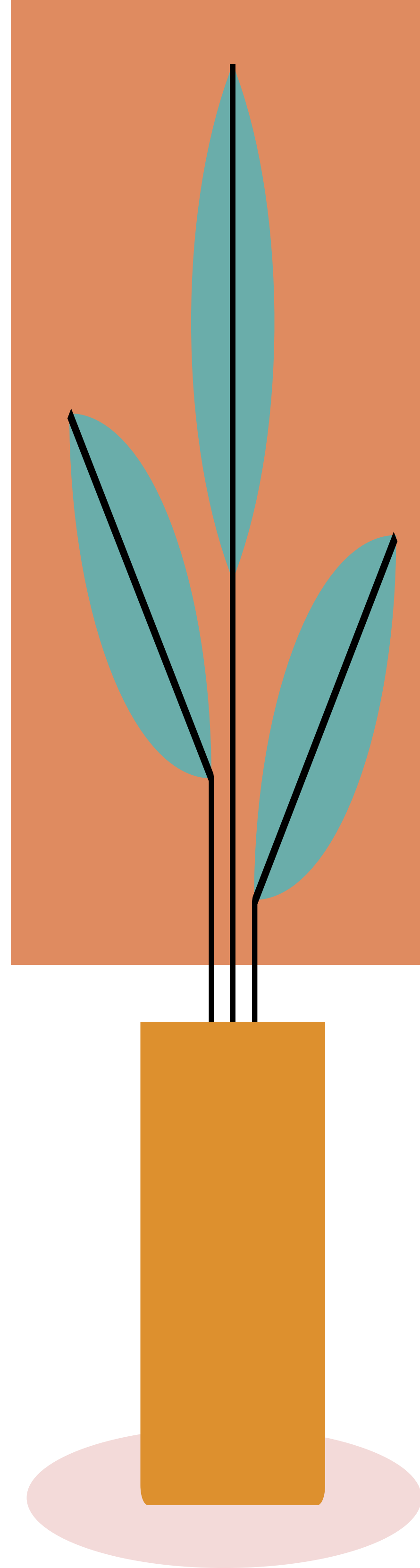
- **Why it is important for you as a doctor to know?**

★ The commonest order prescribed in every hospital
★ Needed for almost every patient
★ Always done by the junior doctors
★ Considered basic medical knowledge
★ Everyone expect you to know it
★ Incorrect prescription can be very dangerous
★ Usually the fluid is available in the floor, so no pharmacist to double check your orders

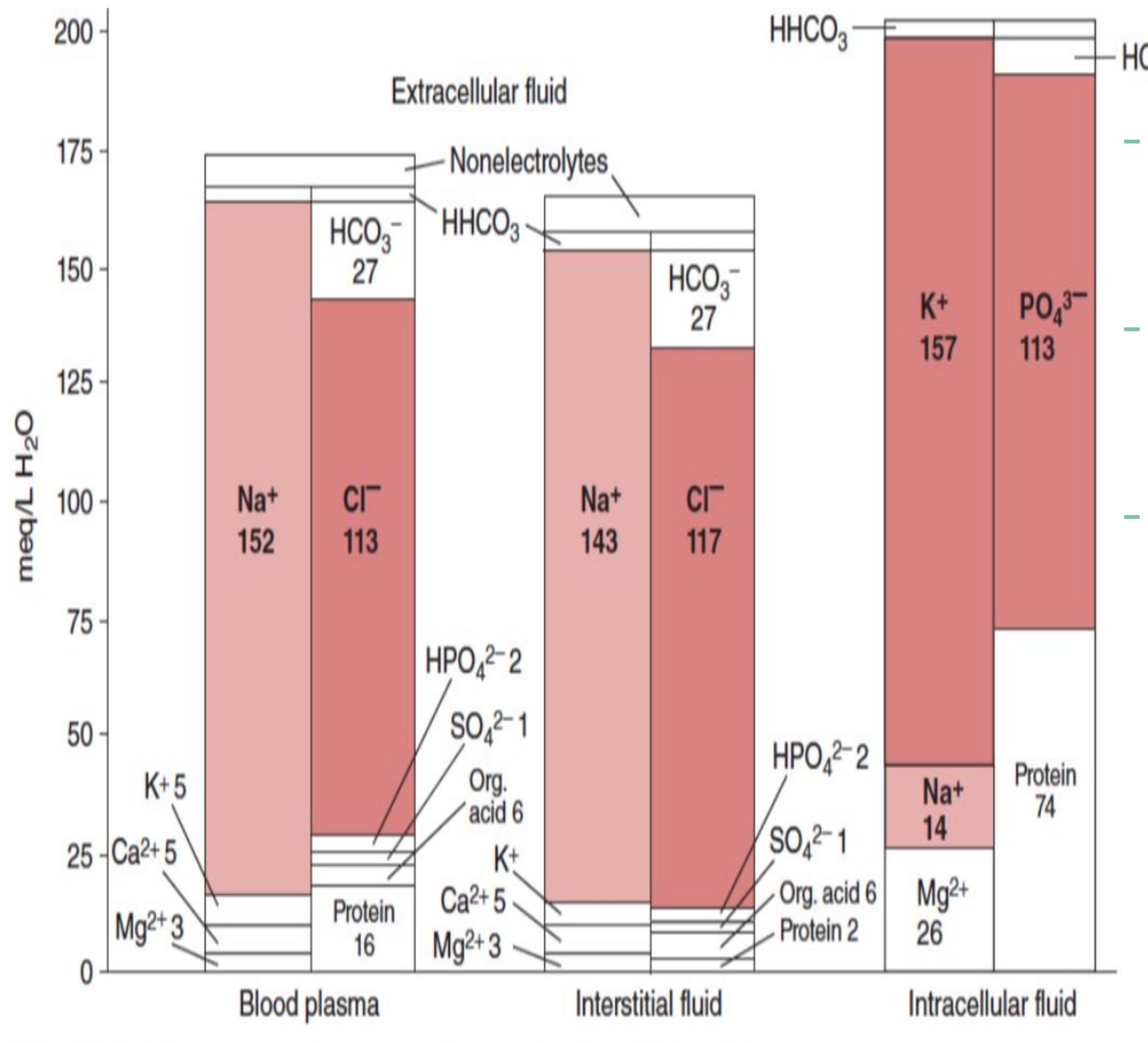
Fluid Compartments

Water & Electrolytes balance:

- **Water makes up around two thirds of our total body mass.**
- 60% of your body weight is water
  - ⅔ of your water is found intracellularly and ⅓ is extracellularly.
  - Extracellular compartment is divided into interstitial 3/4 and intravascular (plasma) 1/4
- **Total body water (TBW) :**
  - **Male:** 60% of body weight (BW).
  - **Female:** 50-55%, because female contain an extra 5% of adipose tissue
- **To calculate TBW needed:**
  - Male sex TBW= BW× 0.6
  - Female sex TBW= BW × 0.5
- **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. This is why pediatrics have more water than elderly
  - **Weight:** the higher level of fat, the lower TBW.



Electrolyte composition of the body compartments:



▲ **Figure 9–1.** Electrolyte composition of human body fluids. Note that the values are in mEq/L of water, not of body fluid. (From Leaf A, Newburgh LH: *Significance of the Body Fluids in Clinical Medicine*, 2nd ed. Thomas, 1955.)

- The most abundant electrolytes in the extracellular fluid: Na,Cl
- The most abundant electrolytes in the intracellular fluid: K,PO4
- A trauma or necrosis of the tissue can lead to hyperkalemia, b/c potassium is present majorly in the intercellular fluid, and trauma affects the cells leading to leakage of fluid outside to the interstitial space then to the intravascular space. (bc the cell will rupture)

Distribution of fluid between intravascular & extravascular spaces depends on:

1. **Pressure:**
   - Oncotic pressure: albumin(Pulling fluid in the vessel)
   - Hydrostatic pressure, forcing the fluid out.
2. **Endothelial permeability**
   - Factors causing Increase in Endothelial permeability allow more fluid to escape from the vessels such as: any inflammation (commonly septic shock)

Hormones affecting water balance:

- Aldosterone & ADH ⟶ Na & water retention
- ANP (Atrial natriuretic peptide) ⟶ Na & water excretion.

Normal Water Loss[1]

Table 1.7 Normal daily losses and requirements for fluids and electrolytes

	Volume (mL)	Na^+ (mmol)	K^+ (mmol)
Urine	2000	80	60
Insensible losses from skin and respiratory tract	700	—	—
Faeces	300	—	10
Less water created from metabolism	300	—	—
Total	2700	80	70

200-300 ml of water is provided endogenously every 24 hours by the oxidation of carbohydrate and fat.
We normally lose most of body water by urination (2L/day)

[1]Normally the body loses 2500-3000 mL every 24 hours from the kidney, skin and GIT

Assessing Fluid/ Electrolytes in Surgical Patients

Table 1.8 Sources of fluid loss in surgical patients		
	Typical losses per 24 hours	Factors modifying volume
Insensible losses	700–2000 mL	↑ Losses associated with pyrexia, sweating and use of nonhumidified oxygen
Urine	1000–2500 mL	↓ With aldosterone and antidiuretic hormone secretion; ↑ with diuretic therapy
Gut	300–1000 mL	↑ Losses with obstruction, ileus, fistulae and diarrhoea (may increase substantially)
Third-space losses	0–4000 mL	↑ Losses with greater extent of surgery and tissue trauma

- Hyperventilation increase insensible water loss via the respiratory tract, but this increase is not actually large unless the normal mechanisms for humidifying inhaled air (the nasal passage and upper airways) are compromised. This occurs in intubated patients or those receiving non-humidified high-flow oxygen. In these situations, inspired gases should be humidified routinely.
- Pyrexia increase water loss from the skin by approximately 200ml/day for each 1C rise in temperature.
- Sweating may increase fluid loss up to 1 liter/hour but these loses are difficult to quantify

★ **Fever:** -200 ml/day for each 1 degree Celsius
★ **Sweating:** up to -1 L/hour & the Na+ > K loss
★ **Effect of surgery:**
  - Stress response:
    - Increase ADH, Aldosterone → urinary retention & oliguria.
  - Third space loss: (interstitial space) fluid اي مكان ما كان فيه fluid وصار فيه
    - In Patient with severe pancreatitis 6L may go to the retroperitoneal space (will become hypotensive)
    - Surgical manipulation resulting in fluid sequestration (seperation) within the tissue (extravascular).
  - Loss of fluid from gastrointestinal tract:
    - Bowel obstruction: no fluid absorption
    - Paralytic ileus: loss of GI function after abdominal surgery for 2-3 days
    - Nasogastric tube, fluid loss كل كمية تطلع من المريض لازم نرجعها كل 4 ساعات تقريباً
    - Stoma or intestinal fistula fluid loss.
    - Diarrhea.

Volume & Electrolyte in GI Fluid

Table 1.9 The approximate daily volumes (mL) and electrolyte concentrations (mmol/L) of various gastrointestinal fluids[a]

	Volume	Na^+	K^+	Cl^-	HCO_3^-
Plasma	–	140	5	100	25
Gastric secretions	2500	50	10	80	40
Intestinal fluid (upper)	3000	140	10	100	25
Bile and pancreatic secretions	1500	140	5	80	60
Mature ileostomy	500	50	5	20	25
Diarrhoea (inflammatory)	–	110	40	100	40
Mixed gastric aspirate	–	120	10	–	–

- In Babies with pyloric stenosis (vomit everything) or patient vomiting 3 times a day there will be increase in the <u>**loss of gastric secretion**</u> which contain hydrochloric and that will cause **hypochloremia** and **metabolic alkalosis**
- If a patient had a tube in his liver to suck all of his bile contents B/C he have obstructed biliary duct will have **metabolic acidosis**
- In case of Diarrhea the patient may develop **hypokalemia**
- Electrolyte solutions is better than water in case of dehydration

IV Fluid Administration

Before ordering IVF, you should ask yourself:

- How much maintenance fluid does the patient need? **4,2,1 formula.**
- Is there any fluid deficit I should add? **If the patient is dehydrated!**
  - (Diarrhea, heatstroke, fever...etc) we should give bolus (20 ml/kg for pediatrics) (500-1000 ml for adults based on the degree of sickness)
  - **Signs** of Dehydration: thirst, dry mucous membranes and oliguria
    - In advanced cases: Tachycardia, hypotension and loss of consciousness
- What fluid compartment I want to replace? **Extracellular or intracellular?**
- Does the patient have any electrolytes disturbance? **Na, K, Cl?**
- What is the type of fluid appropriate for my patient? **Crystalloid or colloid?**
- Does the patient need bolus or continuous fluid?
  - Bolus is fast and large volume in very short time (has to be isotonic)
  - In fluid defect cases

We have 3 methods when it comes to calculating daily fluid requirement:

1. **4,2,1 formula** (most commonly used): Based on body weight *EXTREMELY IMPORTANT*
   - First 10 kg ⟶ multiplied by 4
   - Next 10 kg ⟶ multiplied by 2.
   - The rest of the body weight ⟶ multiplied by 1.
   - The result will be summed & calculated in ml/hr.

Example: Calculate the fluid requirement for a 100kg man:

- First 10kg: 10x4=40
- Next 10kg: 10x2=20
- The rest of body weight (100-20=80): 80x1=80

Total: 40+20+80=140 ml/hr.

- What if we want it per day? Multiply the result by 24, 24x140=3360 ml/day.
- What if he's a child? (not neonate because we don't use this method for them).
  - ➢ If under 10kg, Multiply his weight by 4. (Ex. the child is 5kg, 5x4=20 ml/hr)
  - ➢ If over 10kg, use the same steps for adult (Ex. The child is 12kg, (10x4=40)+(2x2=4)=44 ml/hr

2. **Multiply the weight by 35:** not commonly used
   - A 100 kg man will need > 100x35= 3500 ml/day.
   - If we need it by hour > 3500/24= 145 ml/hr
3. **Add 40 to the weight: This formula is NOT used for pediatrics.**
   - A 100 kg man will need > 100+40= 140 ml/hr.

	Colloids	Crystalloids

Characteristics	• Contain protein particles that exert **oncotic** pressure and cause fluid to remain in the **intravascular** compartment for ~ 6-24hrs
	• Examples:
	  ○ Natural: albumin 5%, 20%. Natural albumin comes from blood donation, so it has the same complications as blood may have (ex. Rejection reaction)
	  ○ Synthetic: Gelatins, Hetastarch, Dextran
	• Colloids are used as a volume expander not for electrolyte imbalance or a physiological condition, just for volume depletion (hypotension) or low albumin.
	• Disadvantages of colloid:
	  ○ Not widely available
	  ○ Take time to prepare and administer
	  ○ Albumin is a blood product (stored in the blood bank)
	  ○ Expensive
	  ○ Can cause allergic reactions, pruritus, coagulopathy
	
	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
		• Containing water and **electrolytes**. (e.g.,sodium, potassium, calcium, chloride)
		• Lack the large proteins and molecules.(So, not given to a patient with hypoalbuminemia)
		Types:
		1. Dextrose solutions (D5, D10, D20 etc.) Glucose + water
		2. NaCl solutions (saline)
		  a. 0.9% normal saline (Standard saline)
		  b. ½ normal saline = 0.45% NS
		  c. ¼ normal saline (usually for pediatrics)
		  d. Hypertonic saline (can rise up to 3% or 5% but it is used very rarely as it may cause brain injury).
		3. Ringer's Lactate (Hartmann's solution)
		Dextrose fluids:
		• Have different concentrations : 5%, 10%, 20%, 50%. (20% and 50% are usually given to hypoglycemic patients)
		• 5% dextrose contain 5gm of glucose in every 100 ml of water (50g/L).
		• After administration:
		  o 60% will go to the intracellular compartment. So majority will leave the blood vessels.
		  o 40% will go to the extracellular compartment (80% interstitial, 20% intravascular).
		• Not good for fluid resuscitation.
		• >12% dextrose can not be administered in peripheral veins (central venous line is needed). لانه يحرق المريض
		• No electrolytes.
		• **Never** bolus any dextrose containing solution because it is hypotonic. If the fluid inside a blood vessel is hypotonic, the water will go inside the cells to balance the tonicity, so the cells will be filled with water and eventually burst. (massive hemolysis) But if the patient is hypoglycemic, it is ok to give him dextrose.
		Crystalloid solutions are classified according to their **"Tonicity"** into 3 categories:
		6 min. video to refresh your memory 😊
		1. Isotonic:
		  a. similar osmolality to the plasma
		    i. 0.9% NaCl (normal saline)
		    ii. Ringer's Lactate (Hartmann's solution)
		  b. 25% will remain in the intravascular compartment.
		  c. 75% will go to the **extravascular compartments.**
		  d. Best option for fluid resuscitation (e.g. rehydration, trauma, perioperative).
		  e. Can be given as bolus or continuous fluid.
		2. Hypotonic: lesser tonicity than plasma, e.g. 2.5% dextrose (¼ NS).
		3. Hypertonic: e.g. 3% normal saline, rarely used (for cerebral edema and management of brain injuries). Can be used in very severe conditions of hyponatremia.

Composition of IV Fluid

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
0.18% NaCl/4% dextrose	31	0	31	0	0	0	0	–	4.0
Ringer's lactate (Hartmann's solution)	131	5	112	Lactate 28[a]	1	1	0	–	6.5
Plasma-Lyte 148	140	5	98	Acetate 27[b] Gluconate 23[b]	0	1.5	0	–	7.4
Haemaccel (succinylated gelatin)	145	5.1	145	0	6.25	0	370	5 hours	7.4
Gelofusine (polygeline gelatin)	154	0.4	125	0	0.4	0.4	465	4 hours	7.4
Human albumin solution 4.5%	150	0	120	0	0		275	–	7.4

[a]The lactate present in Ringer's lactate solution is rapidly metabolised in the body. This generates bicarbonate ions.
[b]The acetate and gluconate present in Plasma-Lyte 148 is rapidly metabolised in the body. This generates bicarbonate ions.
Bicarbonate cannot be directly added to the solutions because it is unstable (tends to precipitate).

IMPORTANT: Normal saline (0.9% NaCl) doesn't have K ions in it, that's why you'll have to include it in the order if the patient needs it.

	Na (mEq/L)	K (mEq/L)	Cl (mEq/L)	HCO3 (mEq/L)	Dextrose (gm/L)	mOsm/L
D5W					50	278
½ NS	77		77			143
D51/2NS	77		77		50	350
NS	154		154			286
D5NS	154		154		50	564
Ringers Lactate (RL)	130	4	109	28	50	272

عشان تسهل عليكم، احفظو النورمال سالاين والباقي بيمشي عليه

مثال: النورمال سالاين فيه ١٥٤ صوديوم، الهاف نورمال سالاين فيه نص ال١٥٤ يعني ٧٧

Is colloid better than crystalloid for fluid resuscitation?

Theoretically, it should be better, but it's **not evident clinically** (survival rate is the same)

EBM 1.1 Crystalloid vs colloid to treat intravascular hypovolaemia

'There is no evidence that resuscitation with colloids reduces the risk of death, compared to resuscitation with crystalloids, in patients with trauma, burns or following surgery.'

Perel P. et al., Cochrane Database Syst Rev. 2007 Oct 17;(4):CD000567

'The use of 4% albumin for intravascular volume resuscitation in critically ill patients is associated with similar outcomes to the use of normal saline.'

Finfer S. et al. The SAFE study. New Engl J Med 2004; 350:2247–2256.

Which goes to which?

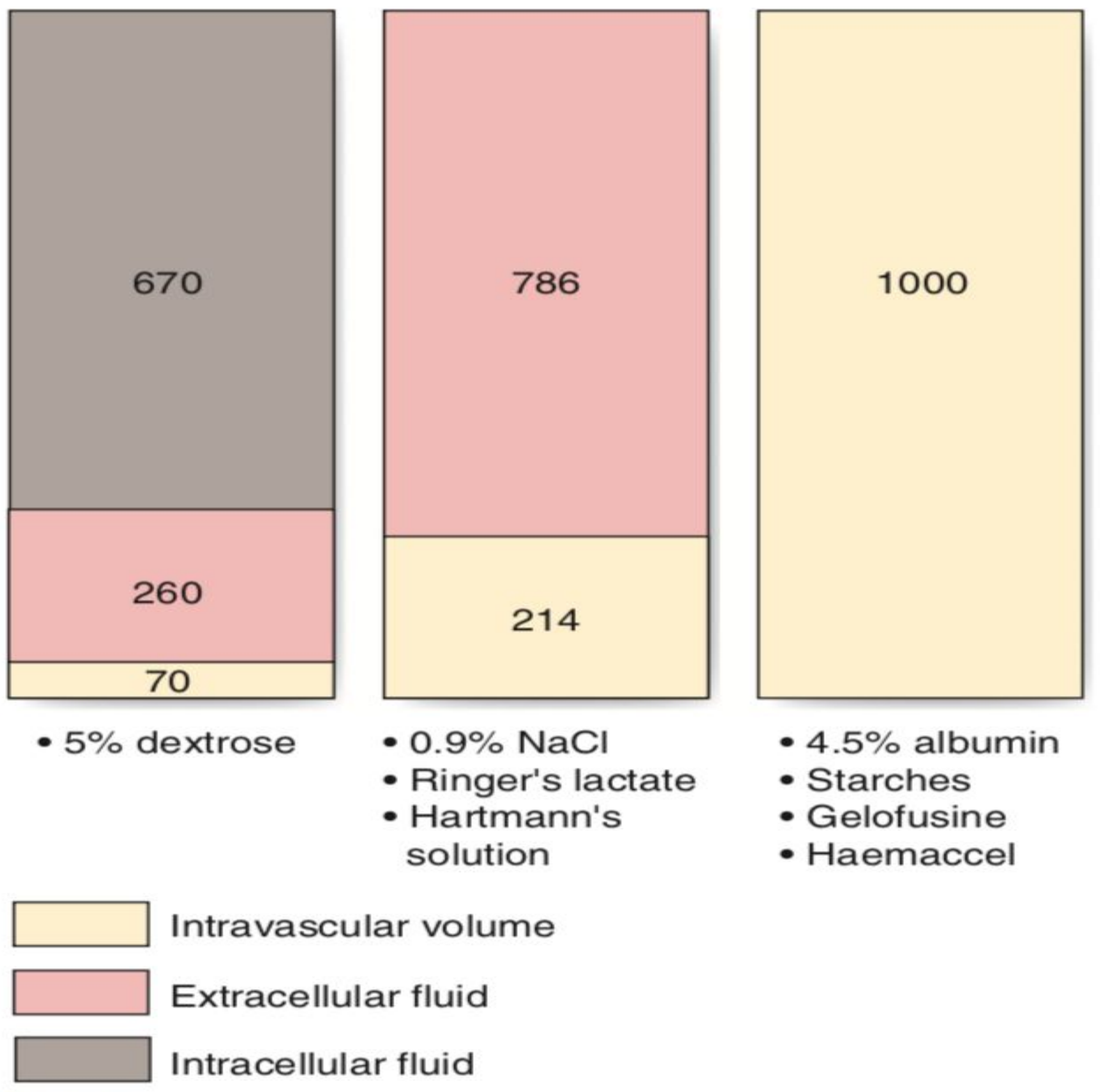


Fig. 1.6 Distribution of different fluids in the body fluid compartments 30–60 minutes after rapid intravenous infusion of 1000 mL.

Electrolytes Requirement

Sodium Requirement

- Adult: Na: 1-2 mEq/kg/day. (to get the requirement, multiply the weight by the normal value).
- Children: Na: 2-3 mEq/kg/day (mmol is the same as mEq)

Example:

- Patient with normal electrolytes weighs 70 kg, requires 70 to 140 mEq NaCl in 2640 ml/d (the first method of calculating fluid requirements 😊).
- In such case, you give the patient **half normal saline**. Why?
- The patient needs 70 to 140 mEq NaCl in 2.6 L a day.
- The half normal saline contains 77 mEq NaCl per liter.
- When you measure it: 2.6L x 77 = 200.2 mEq, It meets the daily requirement of the patient.
- Unlike giving normal saline which contains 154 mEq NaCl per liter. 2.6x154 it will be 400.4, it will exceed the amount needed.

Potassium Requirement

- Adult : K: 1 mEq/kg/day
- Children: K: 2-3 mEq/kg/day.
- **K** can be added to IV fluids. Remember this increases **osmolality** load.
- 20 meq/L is a common IVF additive.
- If significantly hypokalemia, order separate K supplementation.
- *Oral* potassium supplementation is always ***preferred*** if possible.
- Should not be administered at rate greater than 10-20 mmol/hr
    - it can cause thrombophlebitis= an inflammatory process that cause a blood clot to form and block one or more veins

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/day of K+.
- After that you'll add the amount of K+ the patient needs to the fluid you chose to give the patient.

Chloride Requirement

- Adult: 1-2 mEq/kg/day.
- Children: 2-3 mEq/kg/day.

Calculating Fluid Requirement for 70 kg Adult

1. Assuming normal, well hydrated patient, with normal electrolytes.

2. Volume: 4,2,1 formula:
✓ (10x4)+(10x2)+(50x1)= 110ml/hr.
✓ 2640 ml/day.

3. Electrolytes:
✓ Na: 1-2 x 70= 70-140 mEq/day. (Remember: multiply the weight by the normal values of electrolytes to get the range of electrolytes requirement).
✓ K: 1 x 70= 70 mEq/day.

4. Type of fluid:
✓ D5 ½ NS (5% Dextrose + ½ Normal saline) is the best solution. Why?

- If you give 0.9 NS only= 400 mEq/day of Na (too much).
- If you give ½ NS only= 200 mEq/day of Na (acceptable).
- But ½ NS is hypotonic (150mOsmol/L) → adding D5 will raise osmolality to 400 mOsm (acceptable) also will prevent muscle catabolism.

✓ You should add 20mEq KCl/L (so for each litre you get 20 mEq of potassium) to the solution = 52 mEq/day.
✓ Avoid Dextrose in diabetic patient (use ½ NS only).

Your final order: Start IV fluid D5 ½ NS + 20mEq KCl/L @ 110ml/hr.

Explanation:
1. D5: helps suppressing protein catabolism, the patient isn't eating so he needs glucose as a source of energy. It is also needed because the ½ normal saline has low volume, so we include D5 to increase the volume.
2. As we mentioned before, K ions are not available in ½ normal saline, so it has to be supplied or else the patient would be hypokalemic.

Fluid Abnormalities

Water depletion/Dehydration	Water excess
Hypovolemia, a very common condition in surgical patients, usually they lose both water & Na. ● Commonly caused by: ○ Decreased intake. ○ Increased GI loss (diarrhea, vomiting, NGT loss, high stoma output). ● Signs of dehydration: ○ Decrease skin turgor* ○ Dry mucous membranes. ○ Tachycardia. ○ Oliguria <500ml/day (normal: 0.5-1 ml/kg/hr). ○ Hypotension. In very late stages of hypovolemia. ○ Decreased level of consciousness. ● Treatment: ○ Rapid IV bolus of isotonic solution (0.9% NS or LR) ■ Why don't we do all the measures we did before? Because we first need to manage the patient then if he's stable we can do the fluid maintenance methods. ○ 250-1000 ml over 30-60 min. ○ Monitor response to rehydration.	**Hypervolemia**, due to excessive fluid administration (especially hypotonic fluid e.g. Dextrose solution) ● Can cause hyponatremia (dilutional: الموية عشان كثيرة مرة والصوديوم على نفس وضعه فيصير كأنه نقص صوديوم). ● Water accumulates in ECC. ● Difficult to detect clinically (edema, basal chest crackles, elevated JVP). ● Later stages → tissue edema (pitting edema). ● High risk patients: ○ Cardiac failure. ○ Renal failure

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Electrolytes Abnormalities (Sodium)

	Hyponatremia "Sodium Deficit"	Hypernatremia "Sodium Excess"
Diagnosis	- Serum Na < 135 mmol/L - The most commonly encountered electrolyte disturbance in hospital practice	- Serum Na > 145 mmol/L - Results either from water (or hypotonic fluid) loss or sodium gain. It is typically associated with low extracellular fluid volume (hypovolemia).
Causes	- **Hyponatremia** can occur in the presence of decreased, normal or increased extracellular volume. (same as hypernatremia) - The most common cause is the administration of hypotonic intravenous fluids (it will dilute the solute (Na). 1. **Low extracellular fluid volume**: a. Diarrhea. b. Diuretics. c. Adrenal insufficiency. d. Salt-losing renal disease. 2. **Normal extracellular volume:** a. Syndrome of inappropriate ADH secretion (SIADH). b. Hypothyroidism. c. Psychogenic polydipsia. 3. **Increased extracellular fluid volume:** a. Excessive water administration. b. Secondary hyperaldosteronism (cirrhosis, cardiac failure). c. Renal failure	We have 3 types of hypernatremia: 1. **Hypovolemic hypernatremia:** a. Decreased oral intake (e.g. fasting > decreased conscious level)* b. Nausea and vomiting, c. Diarrhea. d. Increased insensible water losses (increases sweating and/or increased respiratory tract losses). e. Severe burns. f. Diuresis (e.g. glycosuria, use of osmotic diuretics). 2. **Euvolemic hypernatremia.** a. Diabetes insipidus (ADH deficiency → polyuria) – central or nephrogenic. For this condition, in the beginning they'll have a normal volume, but if you don't treat them they'll get hypovolemic. 3. **Hypervolemic hypernatremia.** a. Excessive sodium load (hypertonic saline, TPN, sodium bicarbonate). b. Increased mineralocorticoid activity (e.g. Conn's syndrome or Cushing's disease).

Treatment	- Depends of extracellular fluid volume status:
	  - Normal or high: reduce water intake → Na will correct
	  - Low: isotonic fluid administration
	- Avoid rapid correction, because it may lead to brain damage
		- Hypovolemic hypernatremia is treated with isotonic saline.
		- Avoid rapid lowering of sodium (may lead to cerebral edema and permanent brain damage).
		  - Because the brain is used to a specific amount of sodium, and if you reduce it very quickly it's going to pull water in order to balance the solutes which will cause edema

Electrolytes Abnormalities (Potassium)

	Hypokalaemia	Hyperkalemia
Diagnosis	- Very common in surgical patients - Most K is lost via kidneys - Serum K < 3 mmol/L.	- A potentially life threatening condition. - Serum K > 5 mmol/L.
Causes	• **Inadequate intake.** • **Gastrointestinal tract losses:** 1. Vomiting. 2. Gastric aspiration/drainage. 3. Fistulae. 4. Diarrhea. - Because the kidney tries to preserve sodium and water so it leaves potassium to be filtered. 5. Ileus. 6. Intestinal obstruction. 7. Potassium-secreting villous adenoma. • **Urinary losses:** 1. Metabolic alkalosis. 2. Hyperaldosteronism. 3. Diuretics. 4. Renal tubular disorders (e.g. Bartter's syndrome, renal tubular acidosis, drug-induced). • **Transcellular shift-influx of potassium into cells:** 1. Metabolic alkalosis. 2. Drugs (e.g. insulin, B-agonists, adrenaline). • **Consequences:** 1. ECG changes-هايبركاليميا عكس بالضبط- flattened T-waves, U-waves, ectopics). 2. Muscle weakness and myalgia.	• **Excess intravenous or oral intake.** • **Transcellular shift – efflux of potassium from cells:** 1. Metabolic acidosis. 2. Massive blood transfusion. 3. Rhabdomyolysis (e.g. crush &/or compartment syndromes) 4. Massive tissue damage (e.g. ischemic bowel or liver). 5. Drugs (e.g. digoxin, B-receptor antagonists). • **Impaired excretion:** 1. Acute renal failure. 2. Chronic renal failure. 3. Drugs (ACE inhibitors, spironolactone, NSAIDs). 4. Adrenal insufficiency (Addison's disease). • **Consequences**: 1. Arrhythmias (tented T waves, reduced heart rate, heart block, broadened QRS, Asystole). 2. Muscle weakness. 3. Ileus.
Treatment	- Oral K. - IV K for severe cases. - Avoid K IV bolus (can cause arrhythmias)	**In severe hyperkalemia (>7 mmol/L):** 1. Identify and treat cause. Monitor ECG until potassium concentration controlled 2. 10mL 10% calcium gluconate iv over 3 minutes, repeated after 5 minutes if no response antagonises the membrane actions of K+ reducing the risk of ventricular arrhythmias 3. 50mL 50% dextrose & 10 Increases transcellular shift of K units short-acting insulin over into cells 2–3 min. Start infusion of 10–20% dextrose at 50–100mL/h 5. Regular salbutamol nebulisers Increases transcellular shift of K+ into cells 6. Consider oral or rectal calcium Facilitates K+ clearance across resonium (ion exchange resin) gastrointestinal mucosa. More effective in non acute cases of hyperkalaemia 7. Renal replacement therapy Haemodialysis is the most effective medical intervention to lower K+ rapidly

Acid-Base Balance

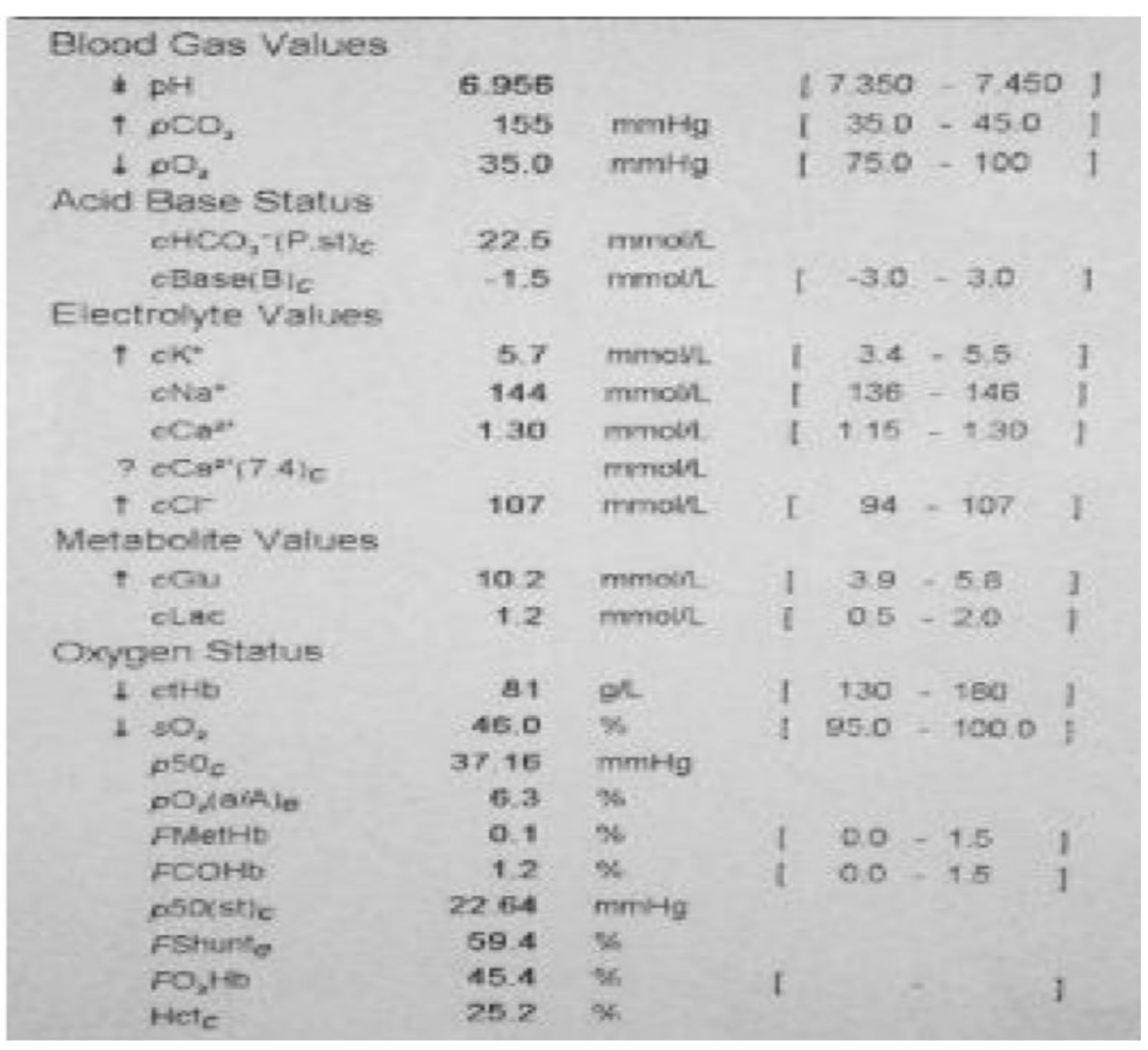
Check this video it is very helpful ([from minute 5 to 19](#))

- **pH:** is the measure of fluid acidity
- **Normal plasma values:**
- pH: 7.35-7.45.
- PCo2: 35-45 mmHg.
- HCo3: 22-26.

Acidosis:	**Alkalosis**:
- pH <7.35 o - Can be respiratory or metabolic	- pH >7.45 - Can be respiratory or metabolic.

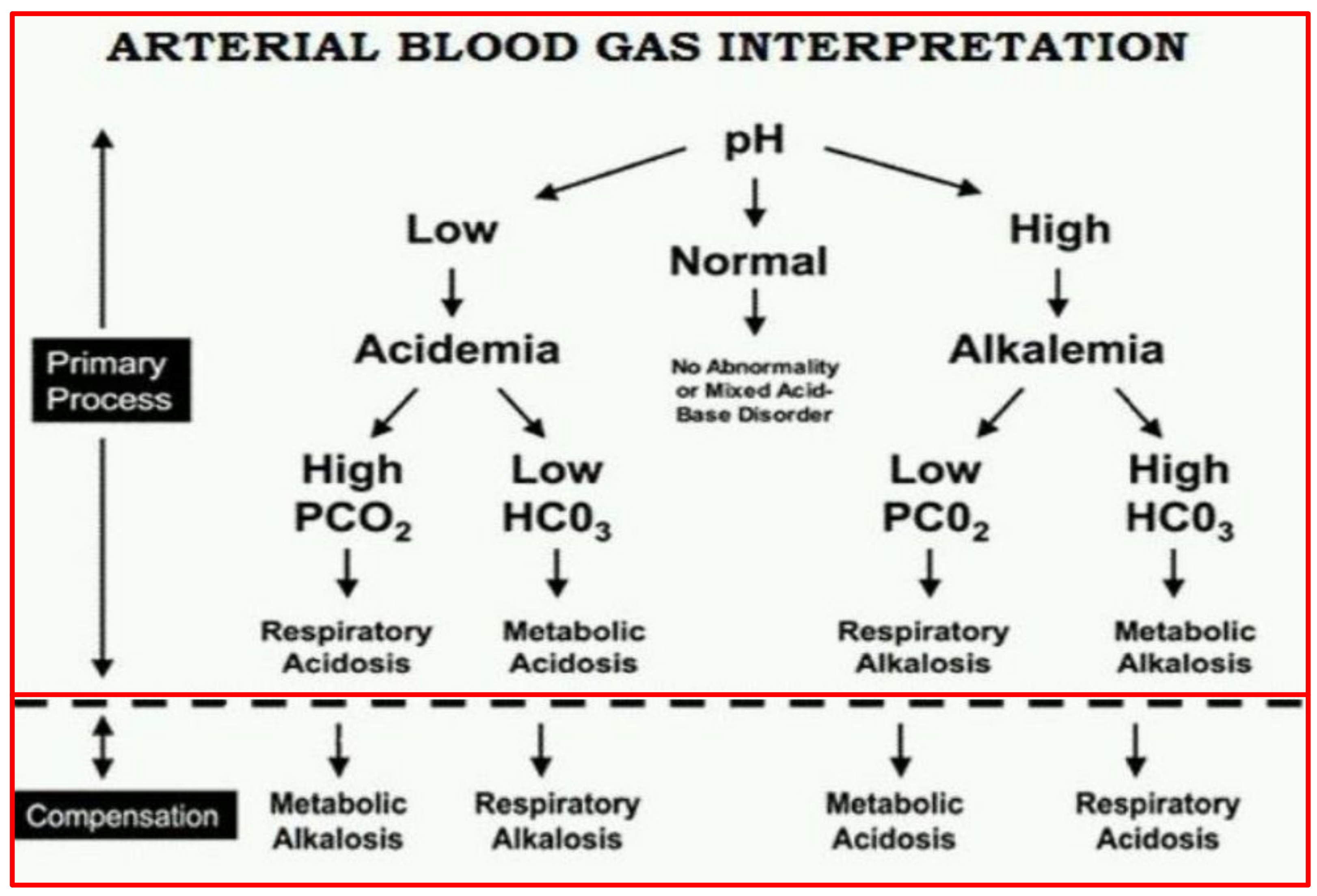
Arterial blood gas (ABG) is the method to analyze acid-base status through arterial blood sample from the radial artery. Venous blood gas is more acidic, and it's less reliable than ABG for detection of PO2.

ABG Results

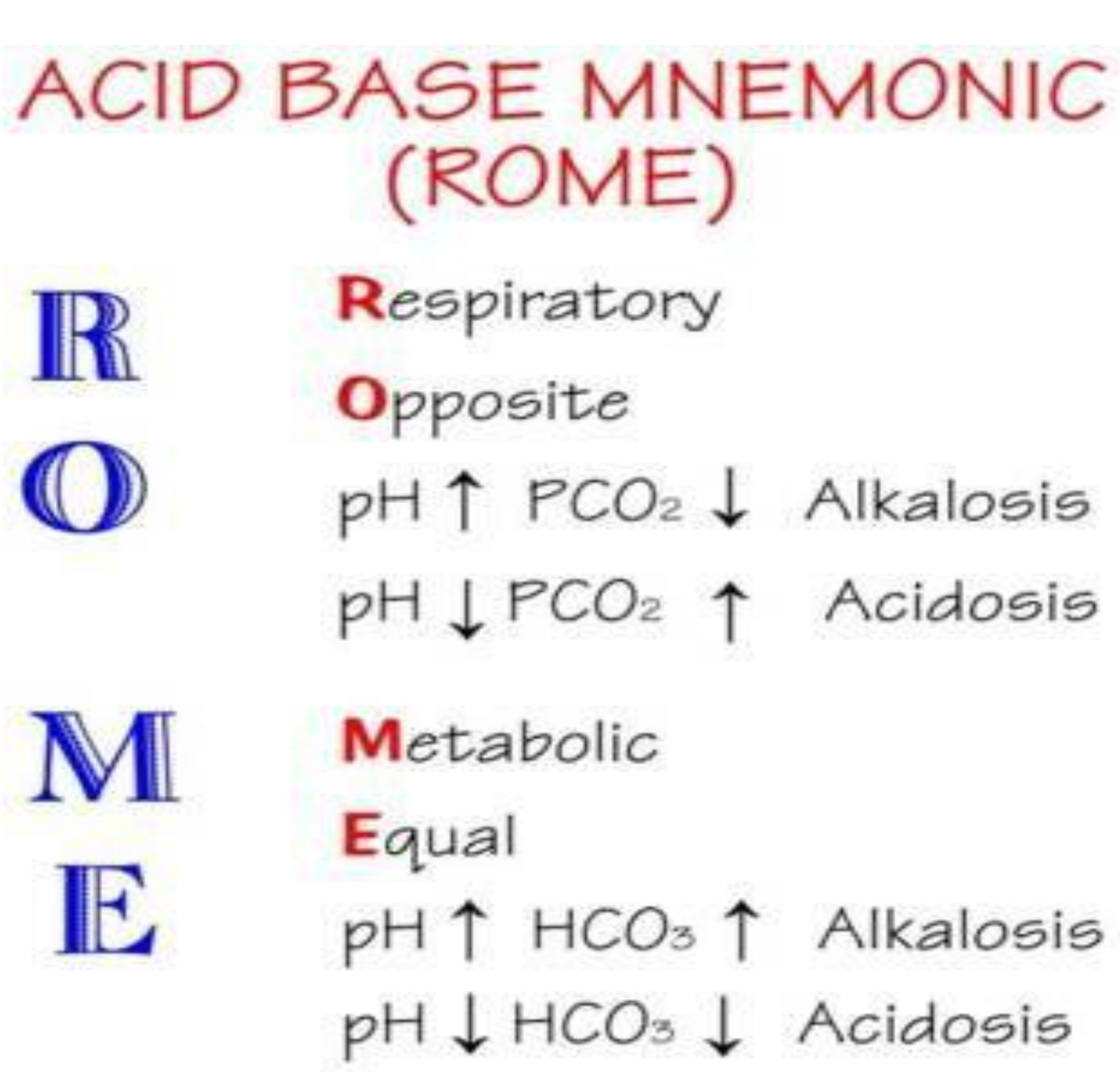


Blood Gas Values			
↓ pH	6.956		[7.350 - 7.450]
↑ pCO_2	155	mmHg	[35.0 - 45.0]
↓ pO_2	35.0	mmHg	[75.0 - 100]
Acid Base Status			
$cHCO_3^-(P,st)_c$	22.5	mmol/L	
$cBase(B)_c$	-1.5	mmol/L	[-3.0 - 3.0]
Electrolyte Values			
↑ cK^+	5.7	mmol/L	[3.4 - 5.5]
cNa^+	144	mmol/L	[136 - 146]
cCa^{2+}	1.30	mmol/L	[1.15 - 1.30]
? $cCa^{2+}(7.4)_c$		mmol/L	
↑ cCl^-	107	mmol/L	[94 - 107]
Metabolite Values			
↑ cGlu	10.2	mmol/L	[3.9 - 5.8]
cLac	1.2	mmol/L	[0.5 - 2.0]
Oxygen Status			
↓ ctHb	81	g/L	[130 - 180]
↓ sO_2	46.0	%	[95.0 - 100.0]
$p50_c$	37.16	mmHg	
$pO_2(a/A)_e$	6.3	%	
FMetHb	0.1	%	[0.0 - 1.5]
FCOHb	1.2	%	[0.0 - 1.5]
$p50(st)_c$	22.64	mmHg	
$FShunt_e$	59.4	%	
FO_2Hb	45.4	%	[-]
Hct_c	25.2	%	

How to read blood gas "important"



Disorder	pH	HCO3-	PCO2
Metabolic Acidosis	⇓	⇓	⇓ Compensatory
Metabolic Alkalosis	⇑	⇑	⇑ Compensatory
Respiratory Acidosis	⇓	⇑ Compensatory	⇑
Respiratory Alkalosis	⇑	⇓ Compensatory	⇓



Acid-Base Balance

	Metabolic Acidosis	Metabolic Alkalosis
Definition	- Increase in plasma hydrogen ions in conjunction with a decrease in bicarbonate concentration. - A rise in plasma hydrogen ion concentration stimulates chemoreceptors in the medulla resulting in compensatory respiratory alkalosis.	- Decrease in plasma hydrogen ion concentration and an increase in bicarbonate concentration. - A rise in PCO2 occurs as a consequence of the rise in bicarbonate concentration, resulting in a compensatory respiratory acidosis.
Common Surgical Causes	1. **Lactic acidosis** -lactate is an anaerobic glycolysis product- a. Shock (any cause) b. Severe hypoxaemia c. Severe haemorrhage/anaemia d. Liver failure 2. **Accumulation of other acids** a. Diabetic ketoacidosis b. Starvation ketoacidosis c. Acute or chronic renal failure d. Poisoning (ethylene glycol, methanol, salicylates) 3. **Increased bicarbonate loss:** a. Diarrhea . b. Intestinal fistulae. c. Hyperchloremic acidosis. Hh	1. **Loss of sodium, chloride and water:** a. Vomiting. (due to the loss of hydrochloric acid) b. Loss of gastric secretions. c. Diuretic administrations. 2. **Hypokalemia**.
Acid-base Findings: not important.	1. **Acute uncompensated:** a. H+ ions ↑ b. PCO2 : normal - Actual HCO3 - ↓ c. Standard HCO3 - ↓ d. Base deficit < -2 2. **With respiratory compensation (hyperventilation):** a. H+ ions go back to the normal value (full compensation) with an increase in the partial compensation. b. PCO2 ↓ c. Actual HCO3 - ↓ d. Standard HCO3 - ↓	1. **Acute uncompensated:** a. H+ ions ↓ b. PCO2 : normal c. Actual HCO3 - ↑ d. Standard HCO3 - ↑ e. Base excess > +2 2. **With respiratory compensation (hypoventilation):** a. H+ ions go back to the normal value (full compensation) with a decrease in the partial compensation. b. PCO2 ↑ c. Actual HCO3 - ↑ d. Standard HCO3 - ↑

Acid-Base Balance

	Respiratory Acidosis	Respiratory Alkalosis
Definition	- A common postoperative problem characterized by increased PCO_2, hydrogen ions and plasma bicarbonate concentrations. - In the surgical patients it usually results from respiratory depression and hypoventilation	Caused by excessive excretion of CO_2 as a result of hyperventilation.
Common Surgical Causes	**1. Central respiratory depression:** a. Opioid drugs (like morphine) b. Head injury or intracranial pathology. **2. Pulmonary disease** a. Severe asthma b. COPD c. Severe chest infection	**1. Pain** **2. Apprehension/hysterical hyperventilation** **3. Pneumonia** **4. CNS disorders (meningitis, encephalopathy)** **5. Pulmonary embolism** **6. Septicemia** **7. Salicylate poisoning** **8. Liver failure**
Acid-base Findings: not important.	1. **Acute uncompensated:** a. H+ ions ↑ b. PCO_2 ↑ c. Actual HCO_3 d. Normal or ↑ e. Standard HCO_3 - normal f. Base deficit < -2 2. **With metabolic compensation (hyperventilation):** a. H+ ions go back to the normal value (full compensation) with an increase in the partial compensation. b. PCO_2 ↑ c. Actual HCO_3 - ↑ d. Standard HCO_3 - ↑↑	**1. Acute uncompensated:** a. H+ ions ↓ b. PCO_2 ↓ c. Actual HCO_3 - normal or ↓ d. Standard HCO_3 - normal e. Base excess > +2 **2. With metabolic compensation (hypoventilation):** a. H+ ions go back to the normal value (full compensation) with a decrease in the partial compensation. b. PCO_2 decrease c. Actual HCO_3 - ↓ d. Standard HCO_3 - ↓

Summary

IV fluids		
Types	crystalloid	colloid
Contains	Water & electrolytes **Except Dextrose** Water & sugar	Water, large proteins, & molecules
E.g	1. **Isotonic:** 0.9% NaCl (normal saline), Lactated Ringer's solution (Hartmann's solution). 2. **Hypotonic:** 2.5% dextrose (1/4 NS). 3. **Hypertonic:** 3% normal saline,	1. **Natural**: albumin 5%, 20%. 2. **Synthetic**: Gelatins, Hetastarch, Dextran

Abnormalities	Treatment
Dehydration	- Rapid IV bolus of isotonic solution (0.9% NS or LR) - 250-1000 ml over 30-60 min. - Monitor response to rehydration.
Water Excesses	Restriction of fluids.
Hyponatremia <135 mmol/L	Depends of extracellular fluid volume status: - Normal or high: reduce water intake> Na will correct. - Low: isotonic fluid administration Because Avoid rapid correction, because it may lead to brain damage.
Hypernatremia >145 mmol/L	Treated with isotonic saline. Avoid rapid lowering of sodium (may lead to cerebral edema and permanent brain damage)
Hypokalemia < 3 mmol/L.	- Oral K. - IV K for severe cases. Avoid K IV bolus (because it can cause arrhythmias).
Hyperkalemia > 5 mmol/L.	1. Identify and treat cause. Monitor ECG until potassium concentration controlled 2. 10 mL 10% calcium gluconate iv over 3 minutes, repeated after 5 minutes if no response — Antagonises the membrane actions of $\uparrow K^+$ reducing the risk of ventricular arrhythmias 3. 50 mL 50% dextrose + 10 units short-acting insulin over 2–3 minutes. Start infusion of 10–20% dextrose at 50–100 mL/h — Increases transcellular shift of K^+ into cells 4. Regular salbutamol nebulisers — Increases transcellular shift of K^+ into cells 5. Consider oral or rectal calcium resonium (ion exchange resin) — Facilitates K^+ clearance across gastrointestinal mucosa. More effective in nonacute cases of hyperkalaemia 6. Renal replacement therapy — Haemodialysis is the most effective medical intervention to lower K^+ rapidly

Quiz!!

1.What are the reasons for using IV fluids?

A. Maintain daily body fluid requirements
B. Replace current body fluid losses
C. Restore previous body fluid losses
D. All the above

2.A solution that is similar to the osmolality of plasma that will cause no cell damage, it is called:

A. Hypotonic
B. Normal Saline
C. Isotonic
D. Hypertonic

3.A solution that is lower in osmolality of plasma that will cause a cell to swell, it is called:

A. Hypotonic
B. Normal Saline
C. Isotonic
D. Hypertonic

4.Why is injuries like burns important to K monitoring?

A. K is used to heal damaged cells.
B. K is released by cells that are damaged
C. K is released from damaged blood cells.
D. K is not important to blood cells but the tissue needs it to function under stress.

5.A doctor understand hypertonic solutions when the doctor states:

A. It has a higher osmolality than plasma It draws fluid out of the cells.
B. It has a lower osmolality than plasma it draws fluid out of the cells.
C. It has a higher osmolality than plasma It pushes fluid into the cells
D. It has a lower osmolality than plasma It pushes fluid into the cells

6.A student is nervous for a big exam and is breathing rapidly, what do you expect out of the followings:

A. Metabolic Acidosis
B. Metabolic Alkalosis
C. Respiratory Acidosis
D. Respiratory Alkalosis

7.The ph of the body fluids is stabilized by buffer systems. Which of the following compounds is the most effective buffer system at physiological pH ?

A. Bicarbonate buffer
B. Phosphate buffer
C. Protein buffer
D. All of the above

8.In a man undergoing surgery, it was necessary to aspirate the contents of the upper gastrointestinal tract. After surgery, the following values were obtained from an arterial blood sample: pH 7.55, PCO2 52 mm Hg and HCO3- 40 mmol/l. What is the underlying disorder?

A. Metabolic Acidosis
B. Metabolic Alkalosis
C. Respiratory Acidosis
D. Respiratory Alkalosis

9.the fluid requirement for a 8kg child per hour is:

A. 42 ml/hr
B. 43 ml/hr
C. 32 ml/hr
D. 33 ml/hr

10.Calculate fluid requirements for a 120 Kg adult

A. D5NS + 30 mEq KCl/L at 160 ml/hr
B. D5 ½ NS + 20 mEq KCl/L at 160 ml/hr
C. D5 ½ NS + 30 mEq KCl/L at 160 ml/hr
D. D5 ¼ NS + 20 mEq KCl/L at 160 ml/hr

1.d 2.c 3.a 4.b. 5.a. 6.d. 7.a 8.b 9.c 10.c