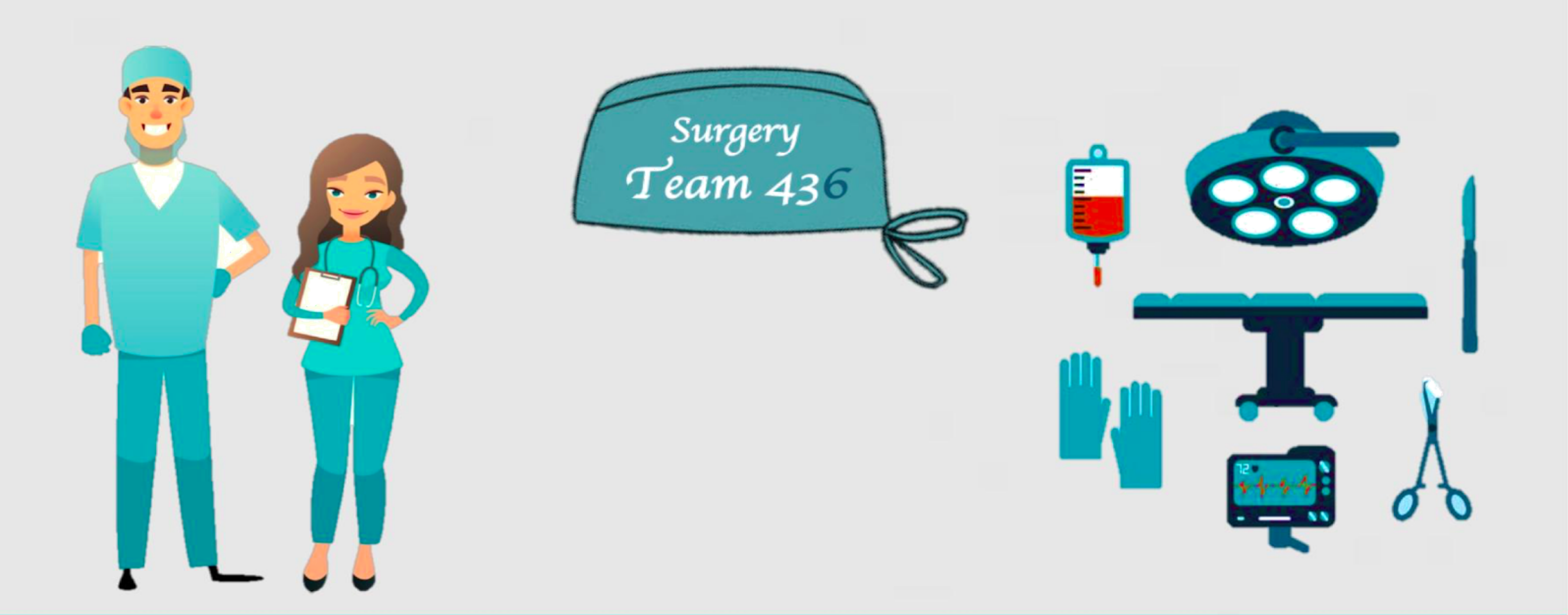


IV fluid and acid base disorder

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

Resources:

- Davidson's.
- 436 doctors slides.
- Surgical recall.
- 435' team work.

Done by: Abdurrahman Almalki, Khalid Aleisa, Shoag Alahmari, Rayan Alqarni
Leaders: Heba Alnasser, Rania Al-Essa, Mohammed Habib, Mohammad Al-Mutlaq
Revised by: Maha Alghamdi

Color index:

Notes , Important , Extra , Davidson's

Editing file

Feedback

Principles of fluid and electrolytes

Introduction:

- **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.
- They are commonly available in volumes ranging from 25 mL to 1,000 mL and are dispensed in either plastic bags or glass bottles.

- **Substances that may be infused intravenously:**

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

- **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

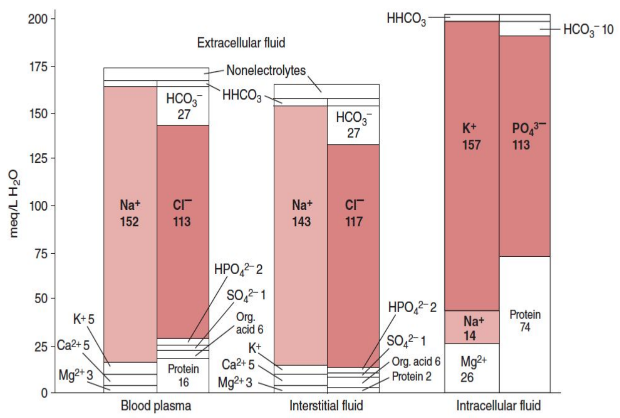
Fluid compartments

General information

- **Water & Electrolytes balance:**
- 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.
- **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.

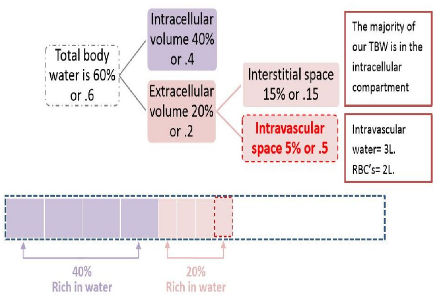
- **Gender:** females have less TBW.
- **Lean body mass (muscle):** increase TBW. This is why pediatrics have more water than elderly
- **Weight:** the higher level of fat, the lower TBW.

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 (including plasma and interstitial fluid): Na, Cl.
- The most abundant electrolytes in the intracellular fluid: K, PO_4.



2/3 of your water is found intracellularly and 1/3 is extracellularly. Extracellular compartment is divided into interstitial and plasma and the interstitiam has water more than the plasma

Distribution of <u>fluid</u> between intravascular and extravascular spaces depends on:

1. Pressures:
- Oncotic pressure: albumin, pulling the fluid in.
- Hydrostatic pressure, forcing the fluid out.
2. Endothelial permeability.

Hormones Affecting water balance:

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

- If the patient has septic shock then the endothelial permeability will increase. So, when we give them fluid to correct the blood pressure, it will remain low because the fluid will go into the interstitial space leading to pitting edema.
- A trauma or necrosis of the tissue can lead to hyperkalemia, because potassium is present majorly in the intracellular fluid, and trauma affects the cells leading to leakage of fluid outside to the interstitial space then to the intravascular space.
- مثال: شخص طاح الجدار على رجله، في هذه الحاله بتموت الخلايا وبيطلع البوتاسيوم خارجها، لكن لو شفنا معدل البوتاسيوم بنلقاه طبيعي، ليه؟ لان الجدار اللي طايح عليه مازال حاشر البوتاسيوم في منطقة محددة.. لكن اول مانرفع الجدار من على رجله بنتفاجئ ان الرجال صار عنده كاردياك اريست! طيب ليش؟ لآن البوتاسيوم اللي طلع من داخل الخلايا انتشر في الجسم بشكل كامل وزي مانعرف ان حالات الهايبر كاليميا ممكن تسوي لنا كاردياك اريست

Normal water loss:

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

Can our body make water?
Yes by manufacturing carbohydrates (about 300ml)

Assessing fluid/electrolytes in surgical patients:

Table 1.8 Sources of fluid loss in surgical patients

	Typical losses per 24 hrs	Factors modifying volume
Insensible losses	700–2000 ml	↑ Losses associated with pyrexia, sweating and use of non-humidified oxygen
Urine	1000–2500 ml	↓ With aldosterone and ADH 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 increases insensible water loss via the respiratory tract, but this increase is not actually large unless the normal mechanisms for humidifying inhaled air (the nasal passages 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 increases water loss from the skin by approximately 200ml/day for each 1℃ increase in temperature. Sweating may increase fluid loss by up to 1 liter/hour but these loses are difficult to quantify.

Volume + Electrolytes in GI fluid:

- Fever:
  - -200ml/day for each 1 degree Celsius
- Sweating:
  - Up to -1L/hr
  - Na>K loss

وش هي الـ3rd space loss؟ لما واحد تجيه اصابه في الركبة مثلا، بتنتفخ ركبته بسبب انتقال الفلود إلى الانترستيشيال سبيل اللي هي تعتبر الـ3rd space.
نفس الشيء لما احد يسوي عملية بينتفخ مكان العملية بسبب انتقال الفلودز. لذلك بعد العملية المريض يحتاج فلودز لانه خسرها لما راحت للانتستيشيم وتركت الخلايا.

- Effect of Surgery:
  - Stress response:
    - Increased ADH, Aldosterone >> urinary retention + oliguria
  - Third space loss:
    - **Surgical manipulation** resulting in fluid sequestration (separation) within the tissues (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
    - Stoma or intestinal fistula fluid loss.
    - Diarrhea .

Table 1.9 The approximate daily volumes (ml) and electrolyte concentrations (mmol/l) of various gastrointestinal fluids*

	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

- You need to know each secretions and what are the electrolytes they contain (including their amounts) to predict the losses the patient may experience if one of them is affected.
- For example: if we remove all the fluid from the stomach which contain hydrochloride, the patient will will have metabolic alkalosis and hypochloriemia.

المريض لما يخسر فلودز يعتمد على المكان اللي خسر منه عشان اقدر احدد وش أكثر الكترولايت خسره.
مثلا مريض خسر دم بتوقع ان الصوديوم عنده قليل لأن الصوديوم موجود بكثرة بالبلازما.
مثلا مريض عنده اسهال بتوقع يكون Hypokalemic لانه خسر بوتاسيوم.

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

Fluids

IVF 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!**
- ✓ 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 > fast (for emergency situations) continuous > slower. REMEMBER NOT TO GIVE A PATIENT A HYPOTONIC SALINE IN BOLUS.

Types of IV fluid:

	Colloids	Crystalloids
Contents	✓ Containing **water** and **large proteins** and **molecules.** • 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 • Contain protein particles that exert **oncotic** pressure and cause fluid to remain in the **intravascular** compartment for ~ 6-24hrs	✓ 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.) 2. NaCl solutions • 0.9% normal saline (Standard saline) • ½ normal saline = 0.45% NS • ¼ normal saline (usually for pediatrics) • 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)

Characteristics	● 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 appropriate for fluid **resuscitation**. E.g: Hypoalbuminemia (due to severe burns, heart failure, sepsis or liver cirrhosis) ⇒ simply give albumin. Loss of blood⇒ simply give blood.	**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: ➢ **60%** will go to the **intracellular compartment.** So majority will leave the blood vessels. ➢ 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). ● **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. 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:** ○ similar osmolality to the plasma e.g. 0.9% NaCl (normal saline), Lactated Ringer's solution (Hartmann's solution). ○ 25% will remain in the intravascular compartment. ○ 75% will go to the **extravascular compartments.** o Best option for fluid resuscitation (e.g. rehydration, trauma, peri-operative). o Can be given as bolus or continuous fluid. 2. **Hypotonic:** have 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. **When administered:** The water take a tour across the 3 fluid compartments (ECF, ICF) depending on the tonicity*. From HYPER to HYPO.

Composition of IV fluid: **IMPORTANT**: you need to know the components of each solution.

Table 1.10 Composition of commonly administered intravenous fluids

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

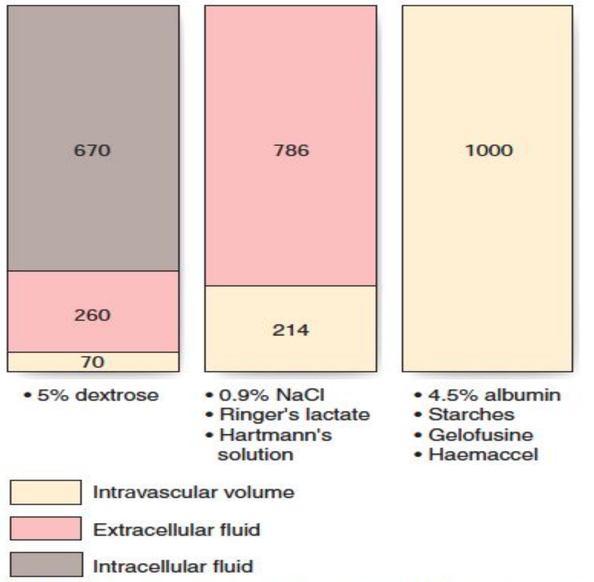


Fig. 1.6 Distribution of different fluids in the body fluid compartments 30–60 minutes after rapid intravenous infusion of 1000 ml.

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.

Is colloid better than crystalloid for fluid resuscitation?
Theoretically, it should be better, but it's not evident clinically

	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

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.

عشان تسهل عليكم، احفظو النورمال سالاين و الباقي بيمشي عليه

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

Normal daily fluid requirement (maintenance):

- 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 and calculated in ml/**hr.**

EXAMPLE: Calculate the fluid requirement for a 100 kg man:
- First 10 kg: 10x4= 40
- Next 10 kg: 10x2= 20
- The rest of the 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 > 140x24= 3360 ml/**day.**

What if he's a child (not a neonate because we don't use this method for them)?
- If he's under 10 kg > multiply his weight by 4. (Ex. The child is 5kg > 5x4= 20ml/hr.
- If he's over 10 kg> use the same steps for the man. (Ex. The child is 12kg> (10x4= 40)+(2x2= 4)= 44ml/hr.

2. **Multiply the weight by 35:**
   - 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.**

Electrolytes requirement

Sodium requirement
● **Adult: Na: 1-3 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 210 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 210 mEq NaCl in 2.6 L a day. ● The half normal saline contains 77 mEq NaCl per liter. ● When you measure it: 2.6 L 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**[1] 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.**

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

<u>Calculating fluid requirement for 70kg adult</u>

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: 1-3 x 70= 70-210 mEq/**<u>day</u>**. (Remember: multiply the weight by the normal values of electrolytes to get the range of electrolytes requirement).
   - ✓ K: 1 x 70= 70 mEq/**<u>day</u>**.
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.

Recall:

What are the fluid requirements every 24 hours for each of the following substances:

Water ≈ 30 to 35 mL/kg
Potassium ≈ 1 mEq/kg
Chloride ≈ 1-2 mEq/kg
Sodium ≈ 1–3 mEq/kg

What are the levels and sources of normal daily water loss?

Urine ≈ 2000 ml/day
Sweat ≈ 700 ml/day
Respiratory losses ≈ 700 ml/day
Feces ≈ 300 ml/day

Fluid abnormalities

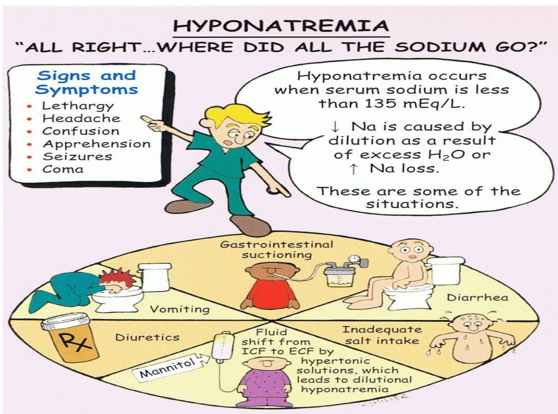
Water depletion/Dehydration	Water excess
Hypovolemia, a very common condition in surgical patients, usually they lose both water & Na. -Commonly caused by: ○ Decreased intake. ○ Increased GI loss (diarrhea, vomiting, NGT loss, high stoma output). -Signs of dehydration: ○ Decreased skin turgor. يعني لما نسحب الجلد ياخذ وقت اطول على مايرجع لوضعه الطبيعي ○ 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: عشان المويه كثيرة مرة و الصوديوم 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.

Electrolytes Abnormalities

<table>
<tr><th colspan="3">Sodium</th></tr>
<tr><td rowspan="2">Diagnosis</td><td>Hypo natremia “Sodium Deficit”</td><td>Hyper natremia “Sodium Excess”</td></tr>
<tr><td><135 mmol/L</td><td>> 145 mmol/L
Results either from water (or hypotonic fluid) loss or sodium gain. It is typically associated with low extracellular fluid volume (hypovolemia).</td></tr>
<tr><td>Causes</td><td>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.

1. Low extracellular fluid volume:
○ Diarrhea.
○ Diuretics.
○ Adrenal insufficiency.
○ Salt-losing renal disease.
2. Normal extracellular volume:
● Syndrome of inappropriate ADH secretion (SIADH).
● Hypothyroidism.
● Psychogenic polydipsia.
3. Increased extracellular fluid volume:
○ Excessive water administration.
○ Secondary hyperaldosteronism (cirrhosis, cardiac failure).
○ Renal failure.


</td><td>We have 3 types of hypernatremia:

1. Hypovolemic hypernatremia:
○ Decreased oral intake (e.g. fasting > decreases conscious level)*
○ Nausea and vomiting,
○ Diarrhea.
○ Increased insensible water losses (increases sweating and/or increased respiratory tract losses).
○ Severe burns.
○ Diuresis (e.g. glycosuria, use of osmotic diuretics).
2. Euvolemic hypernatremia.
○ 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.
○ Excessive sodium load (hypertonic saline, TPN, sodium bicarbonate).
○ Increased mineralocorticoid activity (e.g. Conn’s syndrome or Cushing’s disease).</td></tr>
<tr><td>Treatment</td><td>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</td><td>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.</td></tr>
</table>

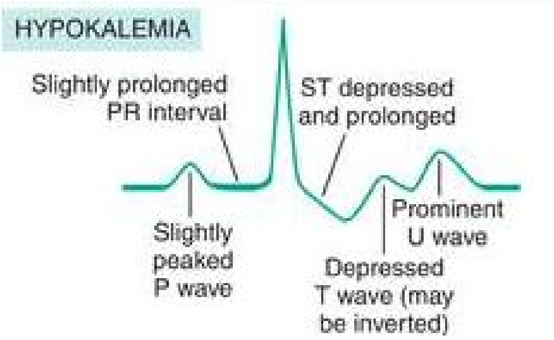
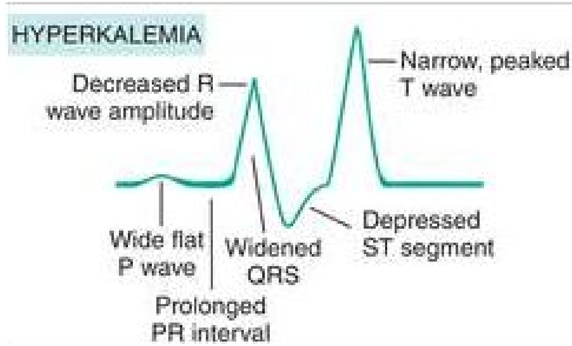
Potassium		
	Hypokalaemia	**Hyperkalemia**
Diagnosis	• **Very common in surgical patients** • **Most K is lost via kidneys** • **Serum K < 3mmol/L.**	• **A potentially life threatening condition.** • **Serum K > 5mmol/L.**
Causes	• Inadequate intake. • Gastrointestinal tract losses: 1. Vomiting. 2. Gastric 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). • Trans-cellular shift-influx of potassium into cells: 1. Metabolic alkalosis. 2. Drugs (e.g. insulin, B-agonists, adrenaline). **Consequences:** 1. ECG changes -بالضبط عكس هايبركاليميا-(flattened T-waves, U-waves, ectopics). 2. Muscle weakness and myalgia. 	• Excess intravenous or oral intake. • Trans-cellular shift – efflux of potassium from cells: 1. Metabolic acidosis. 2. Massive blood transfusion. 3. Rhabdomyolysis -tissue damage- (e.g. crush and/or compartment syndromes) 4. Massive tissue damage (e.g. ischemic bowel or liver). 5. Drugs (e.g. digoxin, B-receptor antagonistis). • 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 (because it can cause arrhythmias).	See the table below.

Table 1.13 Management of severe hyperkalaemia (K^+ >7 mmol/l)	
1. Identify and treat cause. Monitor ECG until potassium concentration controlled.	
2. 10 ml 10% calcium gluconate iv over 3 mins, repeated after 5 min if no response	Antagonizes the membrane actions of ↑ K^+ reducing the risk of ventricular arrhythmias
3. 50 ml 50% dextrose + 10 units short-acting insulin over 2–3 mins. Start infusion of 10–20% dextrose at 50–100 ml/h	Increases transcellular shift of K^+ of into cells
4. Regular salbutamol nebulizers	Increases transcellular shift of K^+ of into cells
5. Consider oral or rectal calcium resonium (ion exchange resin)	Facilitates K^+ clearance across gastrointestinal mucosa. More effective in non-acute cases of hyperkalaemia
6. Renal replacement therapy	Haemodialysis is the most effective medical intervention to lower K^+ rapidly

Be familiar with the 2nd and 3rd management plans, they're the most frequently used ones.

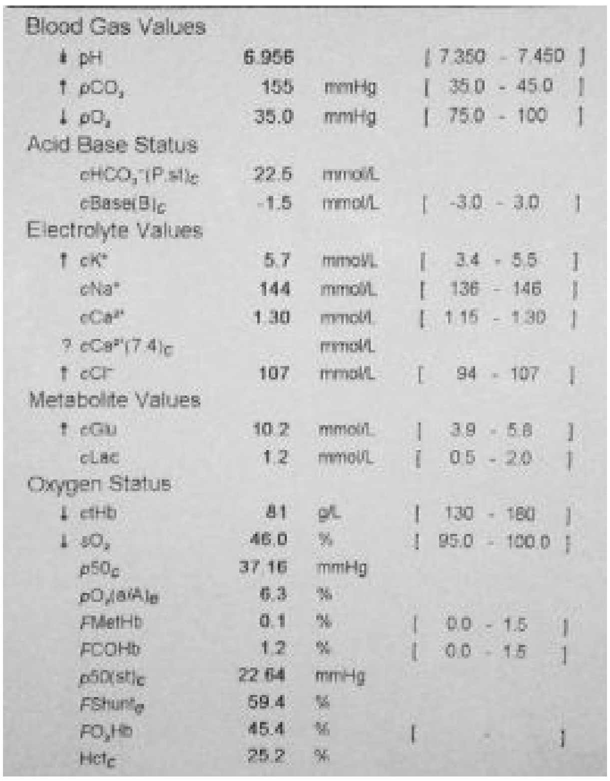
The 2nd management plan is usually used for **cardiac patients to treat arrhythmias.**

Acid-base balance

Normal physiology:

- pH: is the measure of fluid acidity
- Normal plasma values:
  - pH: 7.35-7.45.
  - PCo2: 35-45 mmHg.
  - HCo3: 22-26.
- Acidosis:
  - pH <7.35
  - Can be respiratory or metabolic.
- Alkalosis:
  - 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 result



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

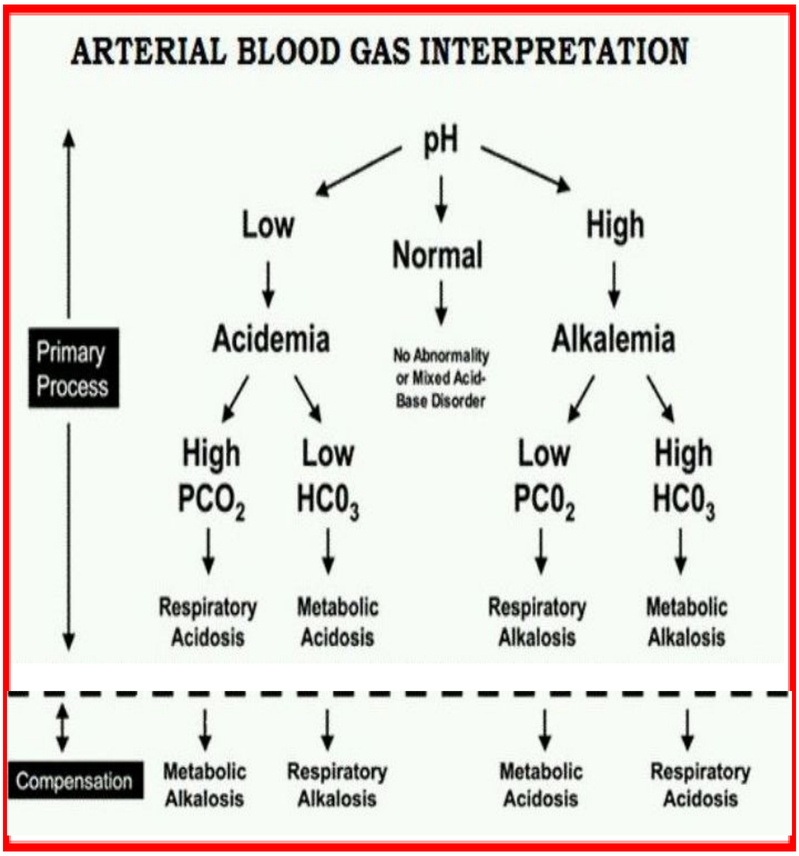


Table 9–3. Changes in HCO_3^- and pCO_2 in primary acid-base disorders.

Disorder	pH	HCO_3^-	Pco_2
Metabolic acidosis	⇓	⇓	⇓ (compensatory)
Metabolic alkalosis	⇑	⇑	⇑ (compensatory)
Respiratory acidosis	⇓	⇑ (compensatory)	⇑
Respiratory alkalosis	⇑	⇓ (compensatory)	⇓

Metabolic acidosis

Characterized by an 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.

Common surgical causes :

1.Lactic acidosis -lactate is an anaerobic glycolysis product-

- Shock (any cause)
- Severe hypoxaemia
- Severe haemorrhage/anaemia
- Liver failure

2.Accumulation of other acids

- Diabetic ketoacidosis
- Starvation ketoacidosis
- Acute or chronic renal failure
- Poisoning (ethylene glycol, methanol, salicylates)

3.Increased bicarbonate loss:

- Diarrhea .
- Intestinal fistulae.
- Hyperchloraemic acidosis.

Acid-base findings: not important.

1.Acute uncompensated:

- H+ ions ↑
- PCo_2 : normal
- Actual HCO_3^- ↓
- Standard HCO_3^- ↓
- Base deficit < -2

2.With respiratory compensation (hyperventilation):

- H+ ions go back to the normal value (full compensation) with an increase in the partial compensation.
- PCo_2 ↓
- Actual HCO_3^- ↓
- Standard HCO_3^- ↓

Metabolic alkalosis

Characterized by a decrease in plasma hydrogen ion concentration and an increase in bicarbonate concentration. A rise in PCo_2 occurs as a consequence of the rise in bicarbonate concentration, resulting in a compensatory respiratory acidosis.

Common surgical causes:

1.Loss of sodium, chloride and water:

- Vomiting. (due to the loss of hydrochloric acid)
- Loss of gastric secretions.
- Diuretic administrations.

2.Hypokalemia.

Acid-base findings: not important.

1.Acute uncompensated:

- H+ ions ↓
- PCo_2 : normal
- Actual HCO_3^- ↑
- Standard HCO_3^- ↑
- Base excess > +2

2.With respiratory compensation (hypoventilation):

- H+ ions go back to the normal value (full compensation) with a decrease in the partial compensation.
- PCo_2 ↑
- Actual HCO_3^- ↑
- Standard HCO_3^- ↑

Respiratory acidosis

A common post-operative problem characterized by increased PCO_2, hydrogen ions and plasma bicarbonate concentrations. In the surgical patients, respiratory acidosis usually results from respiratory depression and **hypoventilation.**

Common surgical causes:

1.Central respiratory depression:

- Opioid drugs (like morphine)
- Head injury or intracranial pathology.

2.Pulmonary diseases:

- Severe asthma
- COPD
- Severe chest infection

Respiratory alkalosis

Caused by excessive excretion of CO_2 as a result of **hyperventilation.**

Common surgical causes:

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:
- H+ ions ↑
- PCo_2 ↑
- Actual HCO_3^- normal or ↑
- Standard HCO_3^- normal
- Base deficit < -2

2.With respiratory compensation (hyperventilation):
- H+ ions go back to the normal value (full compensation) with an increase in the partial compensation.
- PCo_2 ↑
- Actual HCO_3^- ↑
- Standard HCO_3^- ↑↑

Acid-base findings: not important.
1.Acute uncompensated:
- H+ ions ↓
- PCo_2 ↓
- Actual HCO_3^- normal or ↓
- Standard HCO_3^- normal
- Base excess > +2

2.With respiratory compensation (hyperventilation):
- H+ ions go back to the normal value (full compensation) with a decrease in the partial compensation.
- PCo_2 decrease
- Actual HCO_3^- ↓
- Standard HCO_3^- ↓

Recall :

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

Terminologies: Extra

	Definitions
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.

Summary

- We calculate normal daily loss and requirement of fluids by 4,2,1 formula.
- Sources of fluid loss in surgical patient are: 1) insensible loss 2) urine 3) GI tract 4) third-space loss.

Type of IV fluid

	Crystalloids		
According to content	Dextrose	NaCl	Ringer Lactate
According to osmolality	Hypotonic	Isotonic	Hypertonic

Colloids	
Natural e.g.(albumin)	Synthetic e.g. (Gelatins, Hetastarch, Dextran)

Water, electrolytes and acid-base abnormalities

Water imbalance conditions	signs	Treatment
Dehydration	-Decreases skin turgor. -Dry mucous membranes. -Tachycardia. -Oliguria <500ml/day -Hypotension. -Decreased level of consciousness.	Treated by rapid IV bolus (0.9% NS or LR).
Water excess	Difficult to detect clinically (edema, basal chest crackles, elevated JVP).	Restriction of fluids.

Electrolytes imbalance conditions	Treatment
Hyponatremia	Depends upon extracellular fluid volume status: -Normal or high: reduce water intake> Na will be corrected. -Low: isotonic fluid administration.
Hypernatremia	Hypovolemic hypernatremia is treated with isotonic saline.
Hyperkalemia	See table slide (13).
Hypokalemia	-Oral K. -IV K for severe cases.

Acid-base disorders	Arterial blood gases changes
Metabolic Acidosis	**Decrease HCO_3^- compensated by decrease PCO_2**
Metabolic Alkalosis	**Increase HCO_3^- compensated by increase PCO_2**
Respiratory Acidosis	**Increase PCO_2 compensated by increase HCO_3^-**
Respiratory Alkalosis	**Decrease PCO_2 compensated by Decrease HCO_3^-**

Q1/ 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**

Answer : C
EXPLANATION : Fluid requirement = (10)x4 + (10)x2 + 100 = 160 ml/hr ,
Electrolytes requirement : ½ NS only= 292.6 mEq/day of Na (acceptable).
But ½ NS is hypotonic (150mOsmol/L) >> adding D5 will raise osmolality to 400 mOsm (acceptable)
KCl requirement = 120 mEq/day
30 x (0.160 x 24) = 114 mEq/day of KCL (acceptable)

Q2/ What's the daily fluid requirement for 18Kg child (considering 4,2,1 rule) ?

A. **894 ml/day**
B. **1077 ml/day**
C. **650 ml/day**
D. **1344 ml/day**

Answer : D
EXPLANATION : Fluid requirement = (10)x4 + (8)x2 + 0 = 56ml/hr , 56 x 24 = 1344 ml/day

Q3/ 78 y/o Female dehydrated patient with renal failure brought to ER, how could we resuscitate her ?

A. **250 ml NS bolus then D5W**
B. **250 ml ½ NS bolus then D5W**
C. **750 ml ½ NS bolus then D5W**
D. **750 ml NS bolus then D5W**

Answer : A
EXPLANATION : Since she has a chronic disease such as renal failure we'll avoid volume overload, therefore C&D is not the correct answer.
resuscitation with %0.9 NS is ideal for plasma osmolality (286mOsm/L)

Q4/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?

A. 0.7L B. 1.4L C. 2.2L D. 3L

Answer : B

EXPLANATION : Remember that he loses 500 ml / day insensible losses, So :
9 - (6 +1.5) = 1.5 L

2. What would you do with his IV fluids?

A. Continue same IV components with lesser amount
B. Use ¼ NS to dilute his blood
C. Use %3 NS to withdraw fluids from intracellular compartment
D. Stop IV immediately

Answer : D

EXPLANATION : Although he is not drinking, he is overloaded and his IV fluids should be stopped. After a day without IV fluids, he should be euvolaemic, and IV fluids can be recommenced at 2.5 litres a day without overloading him.

Q5/ 5 days after a liver transplant, a 48 year old man has a pyrexia of 40.8℃. His charts for the last 24 hours reveal: Urine output: 2.7 litres. Drain output: 525 ml. Nasogastric output: 1.475 litres. Blood transfusion: 2 units (350 ml each). IV crystalloid: 2.5 litres. Oral fluids: 500 ml. On examination he is tachycardic; his supine BP is OK, but you can't sit him up to check his erect BP. His serum [Na+] is 140 mmol/l.

1. How much IV fluid does he need?

A. 1.7L B. 3.8L C. 5.5L D. 9L

Answer : D

EXPLANATION : His obvious losses (urine + drain + NG tube) total 4.7 litres + His insensible losses are higher than normal because of his fever, and will be about 800 ml, giving a total loss of 5.5 litres + His total intake was 3.7 litres = he is therefore deficient by 1.8 litres
Assuming that his total losses for this day are similar to those of the day before, he will need about 9 litres in order to become euvolemic

2. What fluid would you use?

A. Resuscitate with D5W then mixture of colloid and NS
B. Resuscitate with D5NS then mixture of %3 NS and needed solutes
C. Resuscitate with colloid then maintenance with %0.9 NS
D. Resuscitate with colloid then maintenance with D5 ½ NS

Answer : D

EXPLANATION : NEVER bolus dextrose , it's hypotonic .
He will almost undoubtedly need a mixture of fluids. He will need colloid or further blood in order to fill the intravascular compartment and maintain organ perfusion. He will need saline to replace water and solute losses, and will need some dextrose in order to prevent hypernatraemia. - In practice, a case of this complexity will require repeated re-evaluation, adjustment of his fluids throughout the day with serial blood tests in order to guide you.