430 Surgery Team

Principles of fluid and electrolyte balance in surgical patients

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Terminologies:

- A solvent: is the liquid where particles dissolve in (e.g. Water) that can be measured in liters and milliliters.

- Solutes: are the dissolving particles.

- A molecule: is the smallest unit with chemical identity (e.g. Water consist of one oxygen and two hydrogen atoms = water molecule).

- Ions: are dissociated molecules into parts that have electrical charges (e.g. NaCl dissociates into Na+ and Cl-).

- Cations: are positively charged ions (e.g. Na+) due to loss of an electron (e-) and anions: are negatively charged ions (e.g. Cl-) due to gain of an 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.

- Osmolarity: is the dissolution of a solute in plasma measured in liters, whereas Osmolality is the dissolution of a solute in whole blood measured in kilograms. Therefore, Osmolality is more accurate term because dissolution of a solute in plasma is less inclusive when compared to whole blood that contains plasma (90%) and Proteins (10%).

- Gibbs – Donnan Equilibrium: refers to movement of chargeable particles through a semi permeable membrane against its natural location to achieve equal concentrations on either side of the semi permeable membrane. For example, movement of Cl- from extra cellular 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.

- 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.

Intravenous fluids:

IV fluid is the giving of fluid and substances (electrolytes) directly into a vein

Substances that may be infused intravenously

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

> Cryoprecipitate:
> Any precipitate that results from cooling, sometimes specifically the one rich in coagulation factor VIII obtained from cooling of blood plasma and used in treatment of hemophilia A (antihemopilic factor).

Water makes up around two thirds of our total body mass. To be exact, men are 60% water, whilst women are slightly less at 50-55%.

For example:
A 70 kg. Man will therefore contain about 42 litres, and a 70 kg. Woman near to 38 litres. The reason for this difference between the sexes is that women contain an extra 5% adipose tissue; the difference is only occasionally of clinical significance.

- Total body water is 60% of body weight
- Lean body mass (muscles) (↑ TBW)
- Older age, female sex and fat (↑ BW) are less percent (↓ TBW)
- To calculate TBW needed:
- Male sex TBW= BW× 0.6
- Female sex TBW= BW × 0.5

Body fluid compartments:

- Intracellular volume:

(40%) rich in water

- Extra cellular volume:

(20%) rich in water divided to:

- 15% constitute interstitial space.
- 5% the intravascular space.

Which one of these compartments is most important for us as physicians? And why?

The intravascular space, because this compartment absorbs and loses fluid to the interstitial compartment, or to the Intracellular. It is through this compartment that almost all significant losses and gains occur, so from this compartment we'll see the electrolytes also if the patient is dehydrated by pricking the vessel.

Body electrolytes compartments:

- Intracellular volume

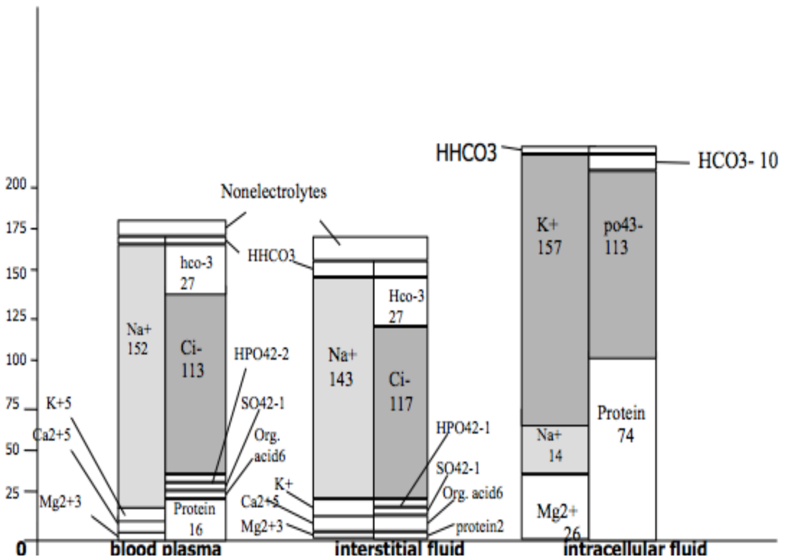
K^+, Mg^+, and Phosphate (HPO_4^-)

- Extra cellular volume (intravascular)

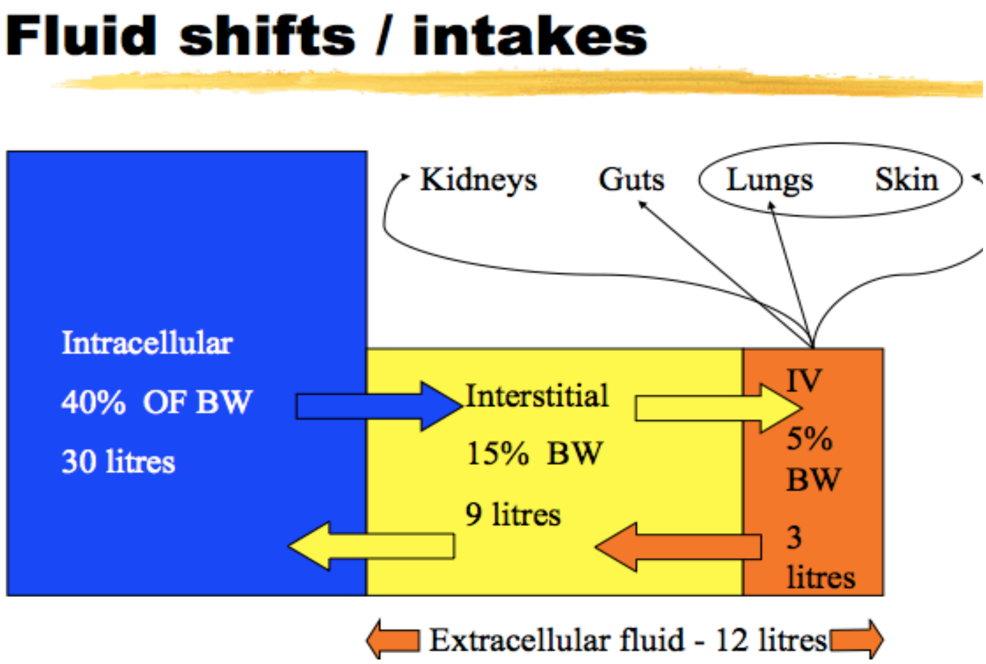
Na^+, Cl^-, Ca^{++}, and Albumin

--The main +ve intracellular electrolyte is K^+
--The main +ve extracellular electrolyte is Na^+
--The main -ve intracellular electrolyte is HPO_4^-
--The main -ve extracellular electrolyte is Cl^-

Normal values of electrolytes



The doctor said that the normal values of the electrolytes in each column should be memorized but the blood plasma (intravascular) column is the most imp.



- The majority of our total body water is locked within our cells; this is the intracellular compartment. Bathing our cells, and occupying extracellular spaces such as the pleural cavity, joint spaces etc., is a smaller amount of interstitial water. Our intravascular compartment holds the smallest amount of water at around 3 litres (a further 2 litres of red cells makes up our total blood volume). The interstitial and intravascular compartments make up our extracellular space.

- Water moves freely between these compartments, but in our day-to-day use, fluids can only be given into, or taken from the vascular space.

- Fluid losses occur mainly from the vascular compartment as well. 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 cannot be measured with ease, and makes up our insensible losses. These amount to 500 ml a day in health (on average), and increase in sickness, particularly when febrile.

Example:
For Fluid Compartments

- 70 kg male: (70x 0.6)
- TBW= 42 L
- Intracellular volume = .66 x 42 = 28 L
- Extracellular volume = .34 x 42 = 14 L
- Interstitial volume = .66 x 14 = 9 L
- Intravascular volume = .34 x 14 = 5 L

Iv fluids:

- Colloids
  Containing water and large proteins and molecules tend to stay within the vascular space.
- Crystalloids
  containing water and electrolytes.

Colloid solutions

- IV fluids containing large proteins and molecules tend to stay within the vascular space and increase intravascular pressure
-Very expensive
- Examples: Dextran, hetastarch, albumin…

Crystalloid solutions

- Contain electrolytes (e.g.,sodium, potassium, calcium, chloride)
- Lack the large proteins and molecules
- Come in many preparations and volume

Classified according to their "tonicity:

- " 0.9% NaCl (normal saline), Lactated Ringer's solution →isotonic,
- 2.5% dextrose→ hypotonic
- D5 NaCl →hypertonic

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

Normal saline fluid (NS 0.9%):

- (NS) — is the commonly-used term for a solution of 0.90% wight/volume of NaCl, about 300 mOsm/L (Na 154, Cl 154) or 9.0 g per liter
- Na is 154 and only CL 154
- No K, NO others

Normal saline has 500 cc (cubic centimeter) how much Na+ is in the bag? 77
Normal saline has 250 cc how much Na+ is in the bag? 34 *1cc=1ml

Hartmann's fluid:

One litre of Hartmann's solution contains:

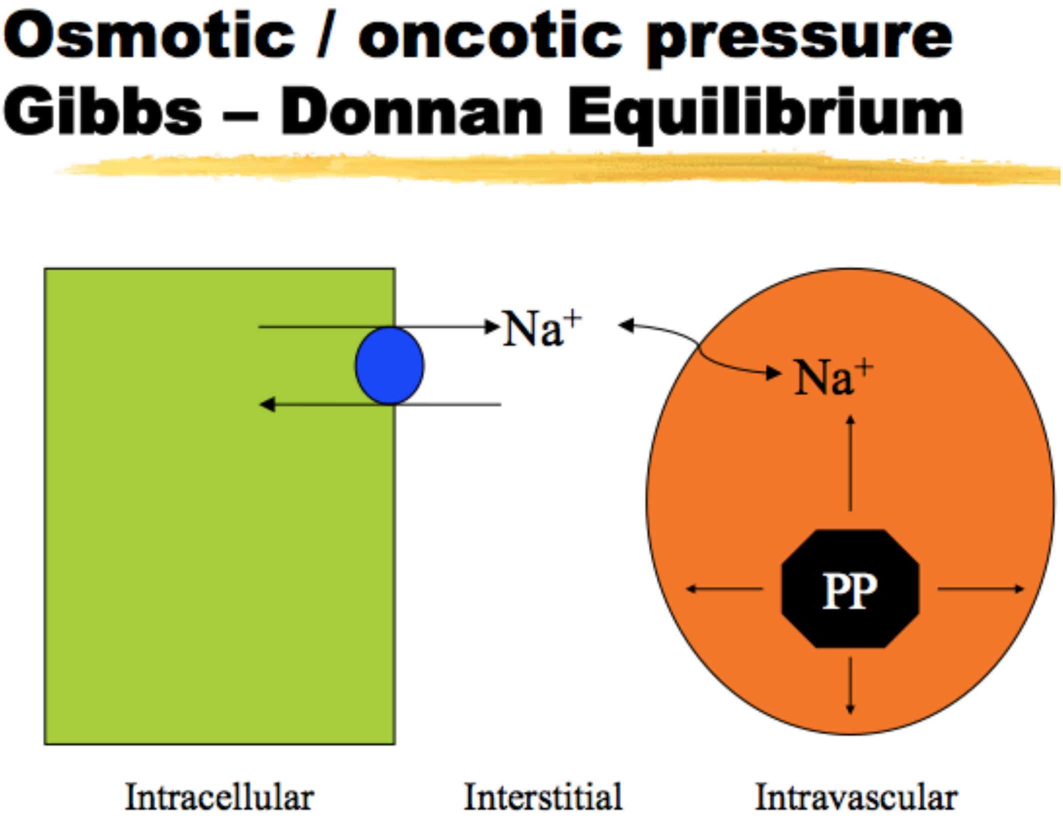
- 131 mEq of sodium ion= 131 mmol/L.
- 111 mEq of chloride ion = 111 mmol/L.
- 29 mEq of lactate = 29 mmol/L.
- 5 mEq of potassium ion = 5 mmol/L.
- 4 mEq of calcium ion = 2 mmol/L. *

Ringer lactate fluid:

One litre of lactated Ringer's solution contains:

- 130 mEq of sodium ion = 130 mmol/L
- 109 mEq of chloride ion = 109 mmol/L
- 28 mEq of lactate = 28 mmol/L
- 4 mEq of potassium ion = 4 mmol/L
- 3 mEq of calcium ion = 1.5 mmol/L *

*mEq is the same as mmol if the electrolyte univalent (e.g. Na+) but if it's divalent it needs to be divided by 2 (e.g. Ca++).



The distribution of water throughout the body is dictated partly by the size of the compartment available (the bigger the size the more fluid it will get), but mainly by tonicity. Water balance is adjusted to maintain osmolality at a constant throughout all three compartments. Furthermore, oncotic pressure generated by large molecules like plasma proteins (PP). Add to the forces that retain water within the vascular space.

Sodium moves freely between the vascular and interstitial spaces, but is actively extruded 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 normalise osmolality.

Calculation of osmolality:

- Difficult: measure & add all active osmoles
- Easy= [sodium x 2] + urea + glucose
- Normal= 280 - 290 mosm / kg

- Normal serum osmolality is 280 - 290 mosm / kg. Measured osmolality uses analysers that measure all active " osmoles ", but a calculated osmolality is often very close. As sodium is the major extracellular cation, the majority of extracellular anions will be equal to its concentration. Urea and glucose make up the remaining significant osmoles, and calculated osmolality is therefore (2 x [Na+]) + [urea] + [glucose]. It is easy to see that in conditions such as hypernatraemia, renal failure (raised urea) or hyperglycaemia, osmolality is raised.

Fluid Requirements:

- Normal adult requires approximately 35cc/kg/d

"4,2,1" Rule l hr

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

Example:
A 100 kg male requires 35x100=3500cc/d

And pair hr:

Two ways either divide 3500/24= ~140cc/hr

Or

Take the first 10 kg and x by 4 = 40
Then the second 10kg and x by 2 = 20
Finally sum them all together 40+20+80= 140cc/hr of water (80 is the rest of the 100 because we took the first two 10's)

This is the amount of water needed to replace daily in this example

Normal fluid output
This assumes normal fluid loss:

- Urine (0.5-1cc/kg/hr).
- Stool.
- Insensible (10 cc/kg/day).
- Watch I/O (input/output) carefully and be aware of other losses.
- Fever increases insensible loss by 200cc/day for each degree (C).
- Monitor abnormal GI loss e.g. NGT suctioning (nasogastric intubation).

Normal daily losses and requirements for fluids and electrolytes

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

WHAT IS THE AMOUNT OF IVF (IV Fluids)?

- In adults remember IVF rate = wt (kg) + 40.
- 70 + 40 = 110cc/hr
- Assumes no significant renal or cardiac disease and NPO if the patient can drink no IVF. [Nil per os (nothing by mouth)]
- This is the maintenance IVF rate; it must be adjusted for any dehydration or ongoing fluid loss.
- Conversely, if the pt is taking some PO, the IVF rate must be decreased accordingly.
- Daily electrolytes, BUN, Cr, I/O, and if possible, weight should be monitored in patients receiving significant IVF.

BUN: blood urea nitrogen
Cr: chromium

* First calculate the maintenance then the defect (if there is a defect) (e.g. burn, diarrhea, ect…)

Fluid shifts in disease

Fluid loss:

- GI: diarrhoea, vomiting, etc.
- Renal: diuresis
- Vascular: haemorrhage
- Skin: burns

Fluid gain:

- Iatrogenic:
- Heart / liver / kidney failure

- Numerous routes exist by which the body can lose or gain fluid. In theory, it is possible to gain or lose pure water, but in most cases, fluid moves along with electrolytes, and the result is determined by the balance of water gains and losses, versus solute gains and losses.

- Do not underestimate the potential for fluid movement. Diarrhoeal illnesses, certain diureses, & fluid retaining states may result in gains or losses of tens of litres of fluid.

Sodium requirement:

- Na: 1-3 meq/kg/day
- 70 kg male requires 70-210 meq NaCl in 2600 cc fluid per day.
- 0.45% saline contains 77 meq NaCl per liter.
- 2.6 x 77 = 200 meq
- Thus, 0.45% saline is usually used as MIVF assuming no other volume or electrolyte issues.

MIVF : Maintenance IV fluid

Example:

Pt. weights 100kg requires 100-300 meq NaCl in 3500 cc fluid/d.
We'll give the patient 0.45% saline because 3.5Lx77= 269.5 meq which meets the daily requirement, if we give the patient 0.9% saline (3.5x154 it will be 539) which is too much.

Potassium requirement:

- Potassium: 1 meq/kg/day
- K can be added to IV fluids. Remember this increases osm load.
- 20 meq/L is a common IVF additive.
- This will supply basal needs in most pts who are NPO.
- If significantly hypokalemia, order separate K supplementation.
- Oral potassium supplementation is always preferred when feasible.
- Should not be administered at rate greater than 10-20 mmol/hr.

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

Abnormalities

Hypokalemia**:**

- Occurs when serum K+<3 mEq/L.
- THE MOST COMMON SURGICAL ABNORMALITY
- Treatment involves KCl i.v. Infusion or orally.
- Should not be administered at rate greater than 10-20 mmol/hr

Causes of hypokalemia: (Reduced/inadequate intake)

1) Gastrointestinal tract losses

- Vomiting
- Gastric aspiration/drainage (The flow of gastric content into the upper respiratory tract due to a ↓ antireflux reflex)
- Fistulae (an abnormal connection between an organ, vessel, or intestine and another structure. It's usually the result of injury,surgery, infection or inflammation.)
- Diarrhea
- Ileus (a disruption of the normal propulsive gastrointestinal track that cause obstruction which prevents bowel contents, such as stool, fluid and gas, from moving through the intestine, which becomes distended)

- Intestinal obstruction
- Potassium-secreting villous adenomas

2)Urinary losses:

- Metabolic alkalosis
- Hyperaldosteronism (characterized by excessive secretion of aldosterone, which causes increases in sodium reabsorption and loss of potassium and hydrogen ions)
- Diuretic use
- Renal tubular disorders (e.g. bartter's syndrome, renal tubular acidosis, amphotericin-induced tubular damage)

Hyperkalemia:

- Causes include increase K+ infusion in IVF, tissue injury, metabolic acidosis, renal failure, blood transfusion, and hemodialysis.
- Arrythmia is the presentation

Causes of hyperkalaemia: (the breakdown of tissues since its located inside cells)

- Hemolysis
- Rhabdomyolysis (is the breakdown of muscle fibers that leads to the release of muscle fiber contents (myoglobin) into the bloodstream)
- Massive tissue damage
- Acidosis……..ARF (Acute Renal Failure)

Management of high K:

- Diagnosis is established by ↑ serum K+>6 meq/L and ECG changes. (when its above 6 they have to be on ECG monitor)
- Treatment includes 1 ampule of D50% + 10 IU Insulin intravenously over 15 minutes, calcium oxalate enemas, Lasix 20-40 mg i.v., and dialysis if needed. (The insulin shift the K inside the cells , given with suger (Dextrose) so it won't affect the persons own suger and lowers it, if I didn't give him sugar and the patient has hypoglycemia then the patient might die)
  U can give orally calcium exalate to get rid of K if it didn't work go for dialysis immediately

Hypernatremia (Sodium excess):

- This is primarily caused by high sodium infusion (e.g. 0.9% or 3% NaCl saline solutions). (Na above 155)
- Another but rare cause is hyperaldosteronism.(What is function? Mentioned above)
- Patients with CHF, Cirrhosis, and nephrotic syndrome are prone to this complication
- Symptoms and sign are similar to water excess. (CNS symptoms: convulsions or coma)

Causes of hypernatremia:

Reduced intake

- Fasting
- Nausea and vomiting
- Ileus
- Reduced conscious level

Increased loss

- Sweating (pyrexia (fever), hot environment)
- Respiratory tract loss (increased ventilation, administration of dry gases)
- Burns

Inappropriate urinary water loss

- Diabetes insipidus (pituitary or nephrogenic) Central or pituitary DI: caused by a lack of ADH, a hormone that conserve water, nephrogenic DI: caused by a failure of the kidneys to respond to ADH)
- Diabetes mellitus
- Excessive sodium load (hypertonic fluids, parenteral nutrition)

Management of hypernatremia:

- Diagnosis is established when serum sodium > 154mEq/L.
- Treatment includes water restriction and ↓ sodium infusion in IVF (e.g. 0.45% NaCl or D5%Water). (Easy treatment, only replace water, because hypernatremia indicates that the body has no water, give more water so the Na goes down)

Hyponatremia(Sodium deficit):

- Causes are hyperglycemia, excessive IV sodium-free fluid administration
  (Corrected Na= BS mg/dl x 0.016 + P (Na)
- Hyponatremia with volume overload usually indicates impaired renal ability to excrete sodium

Treatment of hyponatremia:

- Administering the calculated sodium needs in isotonic solution
- In severe hyponatremia (Na less than 120meq/l): hypertonic sodium solution
- Rapid correction may cause permanent brain damage duo to the osmotic demyelination syndrome (a brain cell dysfunction caused by the destruction of the layer myelin sheath covering nerve cells in the brainstem)
- Serum Na should be increased at a rate not exceeds 10-12meq/L/h.

Water excess:

- caused by inappropriate use of hypotonic solutions (e.g. D5%Water) leading to hypo-osmolar hyponatremia, and Syndrome of inappropriate anti-diuretic hormone secretion (SIADH) (an excessive release of antidiuretic hormone from the posterior pituitary gland or another source)

- SIADH causes: malignant tumors, CNS diseases, pulmonary disorders (pneumonia,lung abscess and others) , medications, and severe stress.

The role of ADH:

- ADH = urinary concentration
- ADH = secreted in response to ⇑ osmo;
- = Secreted in response to ⇓ vol;
- ADH acts on DCT / CD to reabsorb water
- Acts via V2 receptors & aquaporin 2
- Acts only on WATER

(The principle mechanism by which osmolality is maintained is by changes in ADH secretion from the posterior pituitary. 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.
A rise in plasma osmolality increases ADH secretion, whilst a decrease causes ADH secretion to fall.
ADH secretion is also influenced by volume receptors, so that 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 maintenance of normovolaemia.)

Symptoms of excess water:

- Symptoms of water excess develop slowly and if not recognized and treated promptly, they become evident by convulsions and coma due to cerebral edema

Treatment of Excess Water:

- Water restriction and infusion of isotonic or hypertonic saline solution

- In the SIADH secretion. Diagnosis of SIADH secretion is established when urine sodium > 20 mEq/L when there is no renal failure, hypotension, and edema. Treatment involves restriction of water intake (<1000 ml/day) and use of ADH-Antagonist (Demeclocycline 300-600 mg b.i.d).

Water Deficit:

- The most encountered derangement of fluid balance in surgical patients.

- Causes include Bleeding, third spacing*, gastrointestinal losses, increase insensible loss (normal ≈ 10ml/kg/day), and increase renal losses (normal ≈ 500-1500 ml/day).
  - *Third-spacing refers to the loss of extracellular fluid from the vascular to other body compartments where it is no longer available as circulating fluid

Symptoms of water deficit:

- Symptoms of water deficit include feeling thirsty, dryness, lethargy, and confusion.
- Signs include dry tongue and mucous membranes, sunken eyes, dry skin, loss of skin turgor, collapsed veins, depressed level of conciousness, and coma.

Diagnosis of water deficit:

Diagnosis can be confirmed by ↑ serum sodium (>145mEq/L) and ↑ serum osmolality (>300 mOsmol/L)

Treatment of water deficit:

- 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.

It means if sodium is low we give it with water
If sodium is not low then give just water,
If there is something that can cause further loss treat it
If its bleeding give blood, vomiting or diarrhea replace

Signs of hypovolemia and hypervolemia:

Volume depletion	Volume overload
Postural hypotension	Hypertension
Tachycardia	Tachycardia
Absence of JVP @ 45°	Raised JVP / gallop rhythm **
Decreased skin turgor	Oedema
Dry mucosae	Pleural effusions
Supine hypotension	pulmonary oedema
Oliguria	Ascites
Organ failure	Organ failure

The signs of volume depletion or overload can be subtle. Note that some appear in both columns - especially tachycardia.
Postural hypotension, where blood pressure falls on standing or sitting up is a reliable early sign of hypovolaemia, which is often not checked.
** an abnormal heart rhythm marked by the occurrence of three distinct sounds in each heartbeat like the sound of a galloping horse

Hypercalcemia:

- In surgical patients hypercalcemia is usually caused by hyperparathyroidism and malignancy.
- Symptoms of hypercalcemia may include confusion, weakness, lethargy, anorexia, vomiting, epigastric abdominal pain due to pancreatitis, and nephrogenic diabetes insipidus polyuria.

Management of hypercalcemia :

- Diagnosis is established by measuring the free Ca^{++} >10mg/dl.
- Treatment includes normal saline infusion, and if CA^{++}>14mg/dl with ECG changes additional diuretics, calcitonin (lowers calcium and phosphate concentration in plasma), and mithramycin might be necessary

Hypocalcemia:

- Results from low parathyroid hormone after thyroid or parathyroid surgeries, (is secreted by the chief cells of the parathyroid glands acts to increase the concentration of calcium (Ca^{2+}) in the blood,)
- low vitamin D (It facilitates intestinal absorption of calcium, as well as stimulates absorption of phosphate and magnesium ions)
- pseudohypocalcemia (low albumin and hyperventilation) **(**Total serum calcium comprises three major forms: ionized calcium (active form), protein bound ex:albumin,and calcium complexed with anions , so total plasma calcium is low but the ionized free calcium is normal)
- Other less common causes include pancreatitis, necrotizing fascitis, high output G.I. fistula, and massive blood transfusion.

Symptoms and signs of hypocalcemia:

- may include numbness and tingling sensation circumorally (around the mouth) or at the fingers' tips. Tetany and seizures may occur at a very low calcium level. Signs include tremor, hyperreflexia, carpopedal spasms and positive Chvostek sign. The Chvostek sign (also Weiss sign) is one of the signs of tetany seen in hypocalcemia. It refers to an abnormal reaction to the stimulation of the facial nerve.

Treatment of hypocalcemia:

Treatment should start by treating the cause. Calcium supplementation with calcium gluconate or calcium carbonate i.v. or orally. Vitamin D supplementation especially in chronic cases

Hypomagnesaemia:

- The majority of magnesium is intracellular with only <1% is in extracellular space.
- It happens from inadequate replacement in depleted surgical patients with major GI fistula and those on TPN. (Total parenteral nutrition)
- Magnesium is important for neuromuscular activities. (Can not correct K nor Ca)

In surgical patients hypomagnesaemia is a frequently missed common electrolyte abnormality, **as it causes no major alerting symptoms**

Hypermagnesaemia:

- Mostly occur in association with renal failure, when Mg+ excretion is impaired.
- The use of antacids containing Mg+ may aggravate hypermagnesaemia.
- Treatment includes rehydration and renal dialysis.

Hypophosphatemia:

- This condition may result from:

-Inadequate intestinal absorption,
-Increased renal excretion,
-Hyperparathyroidism,
- Massive liver resection
-Inadequate replacement after recovery from significant starvation and catabolism.

Management:

- Hypophosphataemia causes muscle weakness and inadequate tissue oxygenation due to reduced 2,3- diphosphoglycerate levels. (2,3-DPG) A highly anionic organic phosphate which is made in the red blood cells. It controls the movement of oxygen from red blood cells to body tissues
- Early recognition and replacement will improve these symptoms.

Hyperphosphataemia:

Mostly is associated with renal failure and hypocalcaemia due to hypoparathyroidism, which reduces renal phosphate excretion

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

Acid-base balance:

Normal physiology:

- Hydrogen ion is generated in the body by:

1-Protein and CHO metabolism (1meq/kg of body weight)

2-Predominant CO2 production

- It is mainly intracellular
- PH depends on HCO3/CO2
- PH = log 1/[H+]
- Normal PH range = 7.3 – 7.42

  PH<7.3 indicates acidosis

  PH>7.42 indicates alkalosis

Buffers: (A buffering agent adjusts the pH of a solution and prevent any changes)

1- Intracellular
  - Proteins
  - Hemoglobin
  - Phosphate

2- bicarbonate/carbonic acid system

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

The main MECHANISM

HOW DO YOU READ A/VBG: (arterial/venous blood gas)

- PH = 7.3-7.4
- Partial pressure of CO_2 in plasma (Pco_2) = 40 mmHg
- Partial pressure of O_2 in plasma (Po_2) = 65 mmHg
- Bicarbonate concentration (HCO_3) = 24 mEq/L
- O_2 Saturation ≥ 90%
- Base Excess 2.5 mEq/L (<2.5 metabolic acidosis, >2.5 metabolic alkalosis)
- Anion Gap (Na+ - [HCO3+Cl]) = 12 (>12 met. acidosis, < 12 met. alkalosis)

PCo2 in blood: if reaches 80, H will go up ➔acidosis

Bicarbonate (base): if reaches 40 ➔ alkalosis

The calculation of the anion gap is to know the cause of metabloic acedosis

Anion gap:

- AG= Cations (NA+ K) – Anions (CL + HCO3)
- Normal value is 12 mmol above (12 is acidosis)

Metabolic acidosis with:

1-Normal AG (Diarrhea, Renal tubular acidosis)

2-High AG,

-Endogenous (Renal failure, diabetic acidosis, sepsis)

-Exogenous (aspirin, methanol, ethylene glycol)

a person can have metabolic acidosis with normal AG because of a mild decrease in the PH (e.g.7.1)

Acid-base disorders:

- Metabolic acidosis
- Respiratory acidosis
- Respiratory alkalosis
- Metabolic alkalosis

Causes of metabolic acidosis

Lactic acidosis

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

Accumulation of other acids

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

Increased bicarbonate loss

- Diarrhoea
- Intestinal fistulae

(addition of acids or the loss of bicarbonate)

Causes of metabolic alkalosis:

1) Loss of sodium, chloride, water: by vomiting, NGT (nasogastric tube), LASIX (loop diuretic)

2) Hypokalaemia

If you loose K you will get alkalosis, if you gain you will get acidosis

Causes of respiratory acidosis:

- Common surgical causes of respiratory acidosis

- Central respiratory depression
- Opioid drugs medications that relieve pain
- Head injury or intracranial pathology:
- Pulmonary disease
- Severe asthma
- COPD
- Severe chest infection

Hyperventilation (low CO_2)→ respiratory alkalosis
Hypoventilation → respiratory acidosis

Causes of respiratory alkalosis:

- Pain (when you are in pain you hyperventilate)
- Apprehension/hysterical hyperventilation
- Pneumonia
- Central nervous system disorders (meningitis, encephalopathy)
- Pulmonary embolism
- Septicaemia
- Salicylate poisoning
- Liver failure

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