Principles of fluid and electrolyte balance in surgical patients

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Step up medicine
Doctor's notes
Important

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

Lecture Sections:

1) Normal Fluid and Electrolyte compartments
2) Types of intravenous fluids
3) Daily Requirements
4) Prescribing fluids
5) Electrolytes abnormalities
6) Acid-base balance

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1) Normal Fluid and Electrolyte compartments

Fluid:

Total Body water (TBW) = 60% of body weight. (In women it is 50%)
It is influenced by age, sex, and lean body mass. This percentage decreases with age and increase in obesity (fat cells contain very little water).

How is this 60% of water is distributed?
40% is Intracellular (2/3 of water)
+
20% is Extracellular (1/3 of water)→ 15% in interstitial space + 5% in intravascular space.

(Our intravascular compartment holds the smallest amount of water at around 3 liters + a further 2 liters of red cells makes up our total blood volume)

Therefore, 5% of our body weight (Body weight) is water in intravascular space

To calculate TBW:
Male sex TBW= BW× 0.6
Female sex TBW= BW × 0.5

Ex: what is the total body water of a male + weight: 70kg? → 70 x .6=42L
This means his body contains 42 L of water.
+
His 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

Electrolyte:

Most important positive charge intracellular → potassium
Most important positive charge extracellular → sodium
Most important negative charge intracellular → phosphate
Most important negative charge extracellular → chloride

Normal values of electrolytes in blood:
A normal blood sodium level is 135 – 145
A normal blood potassium level is 3.5 - 5.0

Osmotic/Oncotic pressure – Gibbs-Donnan Equilibrium:

Movement of electrolytes depends on gradient. However, if I want to push electrolytes I can push them against a higher gradient. Example: when I Give insulin to move K+ inside the cells by active transportation even though potassium inside is 100 and outside is only 5.

How do you Calculate Osmolality??

Osmolality: (Sodium x 2) + Urea + Glucose → You take blood sample from the patient, and measure the sodium, urea, glucose levels and then you do the equation.
Most important determinant of osmolality is Sodium.
Ex: Patient lab results show Na+: 145, Urea: 2, Glucose: 8
Osmolality = (145 x 2)+2+8= 300
Normal is 280-290

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2) Types of IV fluids:

Colloids → contain **water** and **large molecules** "proteins and glucose".
Ex: Dextran, Hetastarch, and Albumin….
Because colloids contain Large Molecular weight substances, it cannot diffuse to interstitial space, therefore, it tends to stay within the **vascular space.**
→ **Fluid replacement of choice to increase intravascular pressure "blood pressure"**

Crystalloids → contain **water** and **electrolytes.**
Ex: Crystalloids are classified according to their tonicity
Normal saline, and Lactated Ringer's (old name is Hartmann's) → both are Isotonic
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				
5% albumin	150	0				
20% albumin	-	-				
Hes 6% 130/0.4	154	0				
Hes 10% 200/0.5	154	0				
Hes 6% 450/0.6	154	0				

Normal saline: Does not contain Potassium
Ringer's lactate: Contain Potassium
However, we cannot use Ringer's lactate because it is very expensive compared to normal saline…

What is the difference between Normal saline and Half normal saline?
Normal saline (.9%) contains 154 of Na+ and is considered isotonic to human serum.
Half normal saline (.45%) contains half the Na+ that the normal saline contains and is considered hypotonic
Normal saline is the ideal solution for fluid replacement since its tonicity allows most of the fluid to remain in the intravascular space.
Whereas half normal saline is usually used in hypernatremic patients due to its lower Na+ content

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3) Daily Requirements

Fluid:

A healthy person wants to maintain his body fluids. How much should he drink daily? (=What is the Normal daily adult fluid requirements?)

Depends on the weight

Normal Adult requires approximately 35ml of water/kg/day
A 70kg man should get around 2.5L of fluid every day to maintain his body fluids and prevent dehydration.
i.e. 70 x 35 = 2450 ml ≈ 2.5 L

Calculation of Maintenance fluids

A) 4/2/1 rule:
4ml/kg for first 10 kg, 2ml/kg for next 10 kg, 1ml/kg for every 1 kg over 20
Ex: for a 70 kg man: 4x10=40; 2x10=20; 1x50=50. Total (40+20+50)=110ml/hour
110*24=2640ml/day, 2640/70 = 37ml/kg/day

B) Another way → Weight "kg" + 40
Ex: for a 70 kg man: 70 +40 = 110ml/hour

How does a healthy body lose fluids?
Sensible loss → Urine and stool
From insensible losses → sweating, ventilation..etc

You should watch Input/Output carefully and be aware of other losses. The maintenance Intravenous fluid rate should be adjusted for any dehydration or ongoing fluid loss. Ex: diarrhea, vomiting and fever "increases insensible loss"

Electrolytes:
- Na+ requirement: 1-3 meq/kg/day
Ex: a 70 kg male require 70-210 meq Na everyday
Ex2: a 100 kg male requires 100-300 meq Na in 3500 ml fluid everyday. We will give the patient 0.45% saline because 3.5Lx77= 269.5 meq of Na+ which meets the daily requirement, if we give the patient 0.9% saline (3.5x154 it will be 539 Na+) which is too much.
- K+ requirement: 1 meq/kg/day

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4) Prescribing fluids

.45% Saline contains 77meq of Na+ per liter. It contains 2.6 liters of water
So, 77 x 2.6 = 200 meq of Na+ in one bag

Thus, *.45% saline* is usually used as *maintenance intravenous fluid* (MIVF) assuming no other volume or electrolyte issues (patient is fasting)

Because we already said that approximately the daily maintenance requirement of
Fluid → 2.6 L
Na → 70-210 meq
Per day, for a 70 kg man.

When you administer K+, make sure it does not exceed a rate greater than ***20 mmol/hr.*** why?
Because if you give too much K+ you will cause thrombosis of vein or arrhythmias in heart and death

General Rules of fluid replacement:

- Replace blood with blood (However if someone came to ER and he is heavily bleeding in front of you, give Normal Saline immediately. Why? Because it is the fastest, and always available next to you. Do not wait for blood bank to bring blood "the fastest they could bring it to you is after 20 min")
- Replace plasma with colloid (if I want to expand intravascular components and fluid not to go outside vessels I give HMW (High Molecular Weight) substances such as sugar and proteins.)
- Resuscitate with colloid
- Replace ECF depletion with saline
- Rehydrate with dextrose

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5) Electrolytes abnormalities:

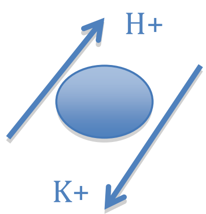
- **HypoKalemia (the most common surgical abnormality)**
- **HypoCalcemia**
- **HyperKalemia**
- **HyperNatremia**
- **HypoNatremia**
- **Hypophosphatemia**
- **HyperPhosphatemis**
- **HyperCalcemia**
- **HypoMagnesemia**
- **HyperMagnesemia**

General rule for causes of Hypo-:
*You do not give electrolyte
*You lose electrolyte
*You consume electrolyte

HypoKalemia:

Occurs when K+ is less than 3
Causes: metabolic alkalosis → which lead to hyper excretion of K+ because the body wants to reabsorb all H+
Vomiting, Fistula, diarrhea, hyperaldosteronism*, diuretics, ileus*….etc

In kidneys:



When treating, as we said K+ administration should not exceed 20 mmol/hr. if >20, patient should be monitored in ICU.

*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)
* hyperaldosteronism: characterized by excessive secretion of aldosterone, which causes increases in sodium reabsorption and loss of potassium and hydrogen ions)

An important cause of Hypokalemia is the administration of saline (contain Na+ but no K+) to a patient who is fasting for several days and did not get K+ → this will not happen if administer ringer's lactate (contain K+)
In other words, hypokalemia is an important surgical abnormality because they always give Saline fluids that do not contain K+.

HyperKalemia:

Occurs when K+ is more than 6
Causes: and metabolic acidosis → which lead to hyper excretion of H+ because the body wants to get rid of the H+.
Increase infusion of K+, tissue injury, renal failure…etc

K+ presents mainly inside the cells. So if you break down the cells, K+ will go to blood
Ex: Hemolysis, Rhabdomyolysis*, massive tissue damage

*Rhabdomyolysis: is the breakdown of muscle fibers that leads to the release of muscle fiber contents (myoglobin) into the bloodstream

If your patient has either Hyper or Hypo kalemia, you should immediately ask for ECG
If there are no changes → just observe
If there are changes in ECG → start treatment (in case of Hyperkalemia, give both insulin and glucose)

Why both Glucose and Insulin are given?
Glucose alone will stimulate insulin from B-cells, but exogenous insulin is more rapid. Give both to prevent hypoglycemia.
Mechanism: this will shift potassium into intracellular compartment

Both Hyper and Hypo Kalemia can present with Arrhythmias

HyperNatremia:

Occurs when Na+ in serum is more than 145
Presentation: Severely Dehydrated
Causes:High sodium infusion → you give .9% normal saline as MIVF for healthy individual→ means 400 Na+ everyday which is a lot (give half normal saline as we said previously)
Dehydration, Hyperaldosteronsims…etc.
Treatment: by giving enough water and low sodium infusion

HypoNatremia:

Presentation: Patient can be:
Normovolemic
Hypervolemic " edematous" → renal impairment
Hypovolemic "dehydrated"
………And each has specific causes. So if a patient came to you with hyponatremia, always check blood volume for differential diagnosis.

Causes: hyperglycemia → in this case you should correct the underlying cause "hyperglycemia" in order for the sodium level to return to normal.

Treatment: Administering the calculated sodium needs in **isotonic solution**

It is very critical to correct hyponatremia slowly NOT RAPIDLY. Why? Because cells now are swollen and while correcting you should not administer Na+ quickly because it might lead to sudden shrinkage of cells and causing permanent brain damage due to the osmotic demyelination syndrome
This means serum Na+ levels should be increased at a rate not exceeding 10-12 meq/L/h.
Ex: you have a hyponatremic patient with Na+110. You give the patient 3% normal saline. After one hour you measure the Na+ level and it is 130. This is too much, so you reduce the administration of normal saline to 2%. After one hour again you check the Na+ levels and it is 132. It is good now……
You have to check serum Na+ levels every hour!

HyperCalcemia:

Occurs when Ca++ in serum is more than 10
Causes: HyperPTH, malignancy…etc
Symptoms: onfusion, weakness, lethargy, anorexia, vomiting, epigastric abdominal pain due to pancreatitis, and nephrogenic diabetes insipidus polyuria.
Treatment: restriction and monitor the heart

HypoCalcemia:

Causes: Results from low parathyroid hormone after thyroid or parathyroid surgeries. Low vitamin D. low albumin and hyperventilation (Pseudohypocalcemia).
Symptoms: CNS exaggeration. numbness and tingling sensation or at the fingers' tips. Tetany and seizures may occur at a very low calcium level. Signs include tremor, hyperreflexia, spasms and positive Chvostek sign. (Chvostek sign: http://www.youtube.com/watch?v=kvmwsTU0InQ)

It is important to check albumin levels in patients with hypocalcemia. If albumin is low, calcium is of course will be low. You must correct albumin level in order for the calcium levels to return to normal.

How can Hyperventilation cause hypocalcemia?
When someone hyperventilates "ex: gets anxious" he/she will get rid of high levels of CO2 and this causes respiratory alkalosis. High pH of blood make the ionized free calcium bind to albumin leading to hypocalcemia.

HypoMagnesemia and Hypophosphatemia:

usually they do not have signs and symptoms
HypoMg → It happens from inadequate replacement in depleted surgical patients with major GI fistula and those on TPN.

Hyperphosphatemia:
Think of a renal disease because it is mostly excreted by the kidneys

HyperMagnesemia:
Important point here: every time you are trying to correct Ca++ or K+ and it is not working, think of HypoMg+. Correct Mg+ and they will be back to normal. The mechanism of this is unknown.

Excess Water
Symptoms: edema everywhere. Cerebral edema leads to convulsions and coma
Treatment: water restriction and look for the underlying cause.

Water Deficit:
It is the most encountered derangement of fluid balance in surgical patients
Causes: Bleeding, third spacing*, gastrointestinal losses, increase insensible, and increase renal losses
* 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
Treatment: look for Na+ levels.
If sodium is > 145mEq/L give 0.45% hypotonic saline solution,
If sodium is >160mEq/L give D5%Water cautiously and slowly, in order not to cause water excess.

What controls water reabsorption and excretion in kidneys? ADH. It is secreted from posterior lobe of pituitary gland
Diabetes insipidus → low ADH
SIADH (syndrome of inappropriate ADH secretion) → high ADH

Diabetes insipidus can be:
- Central or pituitary: caused by a lack of ADH, a hormone that conserves water.
- nephrogenic DI: caused by a failure of the kidneys to respond to ADH
you can give the patient desmopressin (act as ADH) to differentiate between both types. Response occurs with central DI

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6) Acid Base Balance:

Measure the pH.

To measure the pH ask for ABG/VBG
ABG → Arterial blood gas
VBG → Venous blood gas
ABG/VBG measures most importantly: pH, Pco2, Po2, anion gap
Normal PH range = 7.3 – 7.42
PH<7.3 indicates acidosis
PH>7.42 indicates alkalosis

Partial pressure of CO2 in plasma (Pco2) is normally 40 mmHg.:
If Pco2 came 60 → pH will be low
If Pco2 came 10 → pH will be High

Anion Gap: only for one disease. When someone in the beginning has metabolic acidosis. For example: pH is 7.1 and Pco2 is 40 → this is metabolic acidosis NOT respiratory.
Now if I want to know the cause of the metabolic acidosis, I do the anion gap. And I see is it normal or high.

Acid Base disorders:

1- Metabolic acidosis
2- Respiratory acidosis
3- Respiratory alkalosis
4- Metabolic alkalosis

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	↑↑	↑	↑	↑

Causes of metabolic acidosis: Lactic acidosis, Shock, Severe hypoxaemia, Severe haemorrhage/anaemia, Liver failure, Accumulation of other acids, Diabetic ketoacidosis, Acute or chronic renal failure, poisoning (ethyle)
Causes of metabolic alkalosis: Loss of sodium, chloride, water: vomiting, NGT "nasogastric tube", LASIX, **hypokalaemia**
Causes of respiratory acidosis: Central respiratory depression, Opioid drugs, Head injury or intracranial pathology, pulmonary disease, severe asthma, COPD, Severe chest infection.
Causes of respiratory alkalosis: Pain(lead to hyperventilation), apprehension/hysterical **hyperventilation**, pneumonia, central nervous system disorders (meningitis, encephalopathy), **pulmonary embolism**, Septicemia, Salicylate poisoning.

Pulmonary Embolism: In early stages→ respiratory alkalosis. In late stages → Acidosis…

Hyperventilation → Alkalosis
Hypoventilation → Acidosis

Hypokalemia → Alkalosis
Hyperkalemia → Acidosis

Hint: There are some examples in the slides you can go through them.