FLUID/ELECTROLYTE BALANCE

(CHAPTER 8)

QUESTION 1

Identify the two important factors in maintaining fluid balance.

Fluid balance is determined by the difference between **fluid intake** and **fluid output**.

Remember that there is a difference between fluid **balance** and fluid **status**:

Fluid **balance** is a **trend** based on ongoing I/O (gaining or losing water.)

Fluid **status** is based on **current** water content of the body (hypo- or hypervolemic.)

QUESTION 2

Which factors are important in influencing fluid intake?

Oral fluid intake is determined primarily by the **thrirst** drive and personal **habit**.

Thirst is the body's signal to maintain fluid homeostasis, but a person's conscious desire to stay hydrated can also play a role.

QUESTION 3

Which factors are important in influencing fluid output?

Fluid is excreted through multiple mechanisms, but the most important is **urination**.

It is also be lost through defecation (even moreso in the case of **diarrhea**,) **emesis**, and through the skin in **perspiration** and exudate from **burns**.

Consider all of these factors when assessing a patient's I/O; e.g. severe burn patients often require IVF!

QUESTION 4

How can fluid intake be disturbed?

If a patient is **unconscious** or otherwise unable to take in fluid orally, **intravenous fluid** (IVF) therapy may be indicated to achieve adequate intake.

It is important to **monitor I/O** to determine whether adequate fluid balance is being achieved.

QUESTION 5

How can fluid output be disturbed?

Fluid output can be either **increased** or **decreased** through abnormal processes:

Diuresis e.g. due to diabetes (DM or DI,) **emesis**, **diarrhea**, **wound** or **burn** drainage, etc. can all **increase** fluid output.

Urine **retention** due to SIADH, nephrolithiasis (kidney stones,) etc. will cause a **decrease** in fluid output.

QUESTION 6

Describe the relationship between fluid balance and blood pressure.

Water is the major component of blood **plasma** and represents about **half** of whole blood, by volume.

Blood actually represents a **fairly small** proportion of the total fluid in the body (about 7%,) but in general **more fluid volume** means **more blood volume**.

Conversely, **less fluid volume** translates to **less blood volume**. Hence, changes in blood pressure **can** be (but aren't always) related to I/O imbalance.

The terms **hypovolemia** and **hypervolemia** refer to overall fluid **status**, which can result in **ineffective circulation** due to insufficient or excessive BP.

Later in the semester, we'll talk about **hypovolemic shock** and **fluid overload**, two conditions caused by fluid imbalance.

In general, know that low blood volume and high blood volume are **both** bad for circulation.

Hypovolemia **decreases** diastolic filling, leading to lower **stroke volume** (less blood expelled per heartbeat.)

Hypervolemia **increases** diastolic filling and thus **preload**, also lowering SV as the heart is too **stretched out** to function efficiently.

QUESTION 7

List the hormones involved in the regulation of body fluid.

Causing fluid **retention**:

Anti-diuretic hormone (ADH) – produced in the **pituitary gland** in response to increased blood **osmolality** (concentration)

Aldosterone – produced in the **adrenal cortex**, stimulated by angiotensin II and K^+

Causing **diuresis**:

Natriuretic peptides (ANP and BNP) – secreted by the myocardium of the **atria** (ANP) and **ventricles** (BNP) in response to "stretching" of the muscle tissue

QUESTION 8

Describe the functions of these hormones.

ADH maintains the homeostasis of blood **concentration** by **increasing** fluid volume (thus **diluting** the blood) when concentration is too high.

Aldosterone helps maintain the homeostasis of blood **pressure** by encouraging retention of **sodium** (and thus water) in the kidneys.

ANP and **BNP** act against aldosterone, encouraging the **excretion** of sodium when blood pressure is too high.

QUESTION 9

What is syndrome of inappropriate anti-diuretic hormone (SIADH?)

SIADH occurs when the pituitary gland produces **too much** ADH, often due to a pituitary adenoma (tumor,) resulting in **excessive fluid retention**.

When this occurs, ADH levels are **no longer dependent** on blood osmolality and homeostasis breaks down.

The ultimate result is an overall **decrease** in **urine production**, a.k.a. **oliguria**.

QUESTION 10

What is diabetes insipidus (DI?) Compare the central and nephrogenic forms.

In contrast, **diabetes insipidus** (DI) occurs when there is **not enough** ADH activity to maintain fluid balance, leading to **increased** urine production.

Central DI occurs due to **pituitary insufficiency** which causes a decrease in ADH **production**.

Nephrogenic ("kidney-caused") DI occurs due to the kidneys **failing to respond** to the ADH levels in the blood.

Both have the same outcome: the kidneys produce **large amounts** of **dilute** urine, and fluid output **increases**.

Bear in mind this distinction between **hyposecretion** and **receptor resistance**: this is a common theme when discussing endocrine disorders, and understanding this will be a huge help when we get to unit 21.

QUESTION 11

How would urine volume be affected in SIADH?

In SIADH, there is **too much** ADH being produced, signalling the kidneys to **retain** water.

This results in **decreased** urine volume, or **oliguria**.

QUESTION 12

How would urine volume be affected in DI?

In DI, there is **not enough** ADH being produced, or the kidneys are **ignoring** the signal from ADH, causing them to **excrete** more water.

This results in **increased** urine volume, or **polyuria**.

QUESTION 13

Compare the concentration of urine in these two conditions.

In SIADH, the urine that is produced contains **less water**, resulting in a **higher** concentration (high specific gravity, perhaps darker color.)

In DI, the urine contains **more water**, resulting in a **lower** concentration (low specific gravity, perhaps lighter color.)

Let's talk about the body's **internal** fluid balance...

Water movement is determined by balance of two opposing sets of forces:

Filtration forces

vs.

Absorption forces

Filtration forces try to move water *out* of the bloodstream and *into* the surrounding tissue.

These are:

- Capillary hydrostatic pressure (CHP)
- Interstitial fluid osmotic pressure (IFOP)

Absorption forces try to move water *back into* the bloodstream *from* the surrounding tissue.

These are:

- Blood osmotic pressure (BOP)
- Interstitial fluid hydrostatic pressure (IFHP)

Don't worry, it's natural to be confused by this at first.

Let's elaborate...

Each of these sets of forces has a **pushing** force and a **pulling** force that work against the opposite forces on the other side.

Hydrostatic forces always **push**.

Osmotic forces always **pull**.

A **hydrostatic** pressure represents the *actual, physical* pressure of a fluid.

Think of it like the pressure increasing as you inflate a balloon. As you add more air, force pushes out on the balloon, and it inflates.

An **osmotic** pressure represents water's tendency to move towards greater colloidal concentrations.

If the colloids can't balance themselves out, the water will experience a pulling force moving it towards the side with higher concentration.

Let's look at each of the four forces again.

Capillary hydrostatic pressure (CHP) is the **pushing** force caused by the pressure inside your capillaries.

It is the primary force driving **filtration**.

It also **varies** over the length of a capillary—starts out big near the arteriole end, gradually drops by ~50%.

Blood osmotic pressure (BOP) is the **pulling** force caused by the colloids (sodium, albumin, etc.) inside your capillaries.

It is the primary force driving **absorption**.

It remains **constant** over the entire length of the capillary.

Interstitial fluid osmotic pressure (IFOP) is the **pulling** force caused by the colloids present in your **tissues**.

It is a secondary force which contributes to **filtration**.

There are typically fewer colloids in the interstitial fluid than in the blood, so this force is usually small.

Interstitial fluid hydrostatic pressure (IFHP) is the **pushing** force caused by the pressure of fluid in your **tissues**.

It is a secondary force which contributes to **absorption**.

This force is typically small, but if it increases, it will act against filtration.

So what is a **net pressure**?

A **net pressure** is the **total** pressure acting in a direction, **minus** the pressures acting against it.

net filtration pressure = (CHP + IFOP) - (BOP + IFHP)

(both filtration pressures, minus both absorption pressures)

net absorption pressure = (BOP + IFHP) - (CHP + IFOP)

(both absorption pressures, minus both filtration pressures)

A net pressure can go **down** if one of the supporting forces **decreases**, or if one of the opposing forces **increases**, and vice versa.

Towards the arteriole end of a capillary, where CHP is high, there is a **net filtration pressure** and fluid leaves the capillaries.

As fluid leaves and the CHP decreases, it becomes less than the BOP and a **net absorption pressure** is created, drawing fluid back into the capillary.

Keep these concepts in mind as we continue to talk about fluid & electrolyte balance, as well as throughout the semester!

QUESTION 14

Compare hypo- and hypernatremia.

Hyponatremia and **hypernatremia** refer to imbalances in the body's **sodium** (Na^+) level.

One of sodium's primary functions in the body is to direct the **flow of water** throughout the body through **osmosis**.

As such, many of the symptoms of **sodium imbalance** are closely linked with the **fluid imbalance** that they can cause.

Sodium and **potassium** also serve as the body's method of modulating the **electrical potential** of neurons through the **Na^+/K^+ exchange pump**.

This means that extreme imbalances of sodium can also cause **neuromuscular symptoms**, although in reality this is true of most electrolytes due to the fact that they all carry **electrical charge**.

A word of warning:

One of the **recurring themes** you will see when discussing electrolyte imbalances is that the symptoms of **opposite** imbalances can often be **similar**.

Sometimes the sypmtoms will be **opposite as well**, but many times, some of the symptoms will be similar, even if the underlying causes are different.

There is also **lots of overlap** between the kinds of symptoms that imbalances of **different electrolytes** can cause.

As an example of this, **both** hyponatremia and hypernatremia can cause:

Lethargy and **confusion** as changes in oncotic pressure shift fluid in/out of brain cells

Muscle spasms as unstable Na^+ levels interfere with the electrical signaling of neurons

Interestingly, both hyponatremia and hypernatremia can be causes of **edema** (fluid swelling,) which we'll talk about later, due to either decreased oncotic pressure (low Na^+) or increased blood hydrostatic pressure (high Na^+.)

The main difference between hyponatremia and hypernatremia is their effects on **fluid volume**:

Hyponatremia is associated with **hypovolemia** (fluid deficit) due to low Na^+ causing a failure to retain water in the kidneys

Hypernatremia is associated with **hypervolemia** (fluid excess) due to **increased thirst** and increased retention in the kidneys

They also have an effect on the fluid balance of **individual cells**:

Hyponatremia causes cell **swelling** as the lack of sodium decreases osmotic pressure outside of the cell.

Hypernatremia causes cell **shrinkage** as the increased sodium pulls water into the interstitial space.

QUESTION 15

Describe some causes of dehydration.

Dehydration is a deficit in fluid **status**, which can be thought of as a result of a prolonged or acute shift in fluid **balance**.

Either intake is **low** (not drinking enough) or output is **high** (diarrhea, emesis, wound drainage, etc.)

QUESTION 16

Define edema.

Edema is a form of swelling caused by an **excess of fluid** in the **interstitial space**.

You may occasionally hear it referred to as "third-spacing." This is because it is caused by a buildup in the third of the three **fluid spaces**: the intracellular fluid, the bloodstream, and the interstitial space.

QUESTION 17

Describe the potential causes of edema.

Fundamentally, edema arises from an imbalance between the **absorption forces** and **filtration forces** that we spoke about earlier.

When there is a **net filtration force** (filtration > absorption,) fluid will be forced out of the bloodstream and into the tissues, causing edema.

This net filtration force can be caused by:

Increased CHP, e.g. due to **hypertension** or **hypervolemia**

Decreased BCOP, e.g. due to **hyponatremia** or decreased **plasma proteins**

QUESTION 18

Describe how electrolyte imbalances arise.

Like fluid imbalances, **electrolyte imbalances** are also caused by a mismatch between **intake** and **output**.

Intake imbalance can be as simple as having too much sodium or not enough potassium in one's diet.

Output imbalance might include hyperaldosteronism causing sodium retention, or losing potassium due to vomiting.

QUESTION 19

Which tissues are most affected by an electrolyte imbalance?

The tissues that are most affected by electrolyte imbalance tend to be those that use electrolytes to perform their basic functions: specifically, **neurons** and **muscle** tissues.

Of course, this includes the **brain** and **spinal cord**, as well as the **myocardium** of the heart.

QUESTION 20

Describe the effects of potassium (K^+) imbalances.

Because of its role in maintaining the **electrochemical balance** across cell membranes, many of the symptoms of potassium imbalance are **muscle-related**.

Both **hypokalemia** and **hyperkalemia** can result in **cardiac arrhythmias** and even **cardiac arrest**, making severe potassium imbalance a potentially very dangerous condition.

However, the mechanism by which potassium imbalance affects muscle contraction varies:

Hypokalemia tends to prevent muscle **contraction**, leading to **flaccid paralysis**.

Hyperkalemia tends to prevent muscle **relaxation**, leading to **muscle spasms**.

QUESTION 21

Describe the effects of calcium (Ca^{2+}) imbalances.

Hypercalcemia can interfere with brain function, causing **confusion**, **lethargy**, and **fatigue** (similar to sodium imbalances.)

Hypocalcemia interferes with the Na^+/Ca^{2+} balance of **muscle cells**, causing **cramps**, **spasms**, and **tetany**.

Hypocalcemia may also result in **paresthesia** (tingling/numbness) in the extremities and around the mouth.

QUESTION 22

Describe the effects of magnesium (Mg^{2+}) imbalances.

The classic effect of **magnesium** imbalances is the alteration of the **reflexes**.

Hypomagnesemia will tend to result in **hyperreflexia**, or **increased** reflexes.

Hypermagnesemia will tend to result in **hyporeflexia**, or **decreased** reflexes.

Aside from causing increased reflexes, **hypomagnesemia** can result in **tremors** or **spasms**, **loss of appetite**, and **nystagmus** (involuntary eye movement.)

Aside from causing decreased reflexes, **hypermagnesemia** can result in **weakness**, **confusion**, and **cardiac arrhythmias** through interaction with calcium in the heart.

QUESTION 23

Describe the effects of phosphate (PO_4^{3-}) imbalances.

The main thing to remember about phosphate imbalances is that there is an **inverse relationship** with calcium; **high phosphate** levels **decrease calcium**, and vice versa.

They are also closely linked because bone matrix is composed of hydroxyapatite, which is primarily calcium and phosphate.

For phosphate imbalances, think about what the **opposite** calcium imbalance would do:

Hypophosphatemia, like **hypercalcemia**, can cause **muscle weakness**.

Hyperphosphatemia, like **hypocalcemia**, can result in **twitching** and **muscle spasms**.