FLUID/ELECTROLYTE BALANCE

(CHAPTER 8)

QUESTION 1

Which body compartment contains the most fluid?

Most fluid in the body is **intracellular**—contained in the cytosol of cells. (About a 2:1 ratio)

Breakdown by body weight:

- 40% solid
- 40% intracellular fluid
- 20% extracellular fluid

QUESTION 2

What is the amount of active drug in most prescriptions? Give an example.

Most medications have extremely **small** dosage relative to body mass, often expressed in **milligrams**.

Some may even have dosage expressed in **micrograms** (µg/mcg)

Cells are very tiny, and it doesn't take much of a substance to alter their physiology.

QUESTION 3

How do newborns differ with respect to water content?
Why do newborns lose weight in the neonatal period?

Newborns made of about 75-80% fluid, rather than 60% like adults are. Most of this excess water weight is lost in the first 1-3 days after birth.

Environment of the womb causes extra water to be absorbed; once homeostasis kicks in, fluid imbalance is quickly corrected.

QUESTION 4

Why is fat ideal for the storage of excess energy?

Several reasons:

- **Dense** form of energy storage—catabolism yields over twice as much ATP vs. carbohydrates by mass
- Triglycerides are shredded completely during lipolysis and fatty acid metabolism, leaving only CO_2 and H_2O. **Lots** of energy produced per molecule!
- Glycogen (carbohydrate) stores are not broken down as thoroughly, and need lots of water to be stored in hydrated form

QUESTION 5

Would an obese person have more or less body water? Why?

By percentage, **less**. Lean tissues still contain the same ~60% water, but adipose tissue contains far less due to being mostly composed of fat.

The more adipose tissue a person has, the more this difference brings the total water percentage down.

QUESTION 6

What forces determine water movement between the capillaries and the interstitial fluid?

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.

QUESTION 7

Why do dents form under a stretching band if it is left on the wrist overnight?

External forces on the body can increase the **interstitial fluid hydrostatic pressure**.

This works against the filtration pressures and pushes fluid out of the tissues, back into circulation.

QUESTION 8

Changes in which of the forces will lead to edema?

oídēma (swelling)

EDEMA

"an excessive accumulation of fluid in the tissues or body cavities"

Edema is caused by an increase in **net filtration pressure**, leading to increased interstitial fluid.

Based on this, what might cause it?

Increased filtration forces:

- Increase in capillary hydrostatic pressure (CHP)
- Increase in interstitial fluid osmotic pressure (IFOP)

Decreased absorption forces:

- Decrease in blood osmotic pressure (BOP)
- Decrease in interstitial fluid hydrostatic pressure (IFHP)

Because of the magnitudes of the four forces, it tends to be either **increased CHP** or **decreased BOP**. We will discuss both of these in the next few questions.

QUESTION 9

What role does protein play in the plasma? Why?

Proteins float freely in the blood plasma, meaning they are **colloids**.

Albumin in particular is one of the major contributors to blood osmotic pressure (BOP).

less proteinspan class="fragment fade-up"> → lower absorption pressurespan class="fragment fade-up"> → fluid stays in tissues

QUESTION 10

How would capillary hydrostatic pressure increase?

Usually associated with some sort of disruption of normal blood flow. Blood gets "backed up" into capillaries and is pushed out into tissues.

The location of the edema is closely linked to the location of the backup—always "upstream."

Also associated with **volume overload** (hypervolemia,) high blood pressure due to **too much** fluid in blood. Can be caused by kidney failure due to increased salt/water retention.

QUESTION 11

What may cause pulmonary edema? Systemic edema?

Pulmonary edema – **left heart failure**

Problem is in the left side of the heart. What's "upstream" from the left heart?

Presure backs up into left atrium, then pulmonary vein, into the lungs. Fluid is pushed out of alveolar capillaries by CHP and builds up in the lungs.

Systemic edema – **right heart failure**

Problem is in the right side of the heart. What's "upstream" from the right heart?

Presure backs up into right atrium, then venae cavae, into the systemic venous circulation. Results in **generalized** edema.

QUESTION 12

What may cause a change in the plasma oncotic pressure?

Plasma oncotic pressure: same as BOP.

What affects this?

liver failure – reduced albumin production leads to hypoalbuminemia

poor nutritional status – insufficient amino acids to produce needed proteins

nephrotic syndrome – protein lost in urine

QUESTION 13

What is the normal plasma protein percentage per 100 ml?

7%. About 4 out of this 7% (a little over half) is albumin.

QUESTION 14

A dysfunction in which organ would lead to a decrease in plasma protein?

Kidney disease, e.g. **glomerulonephritis** can cause plasma proteins to be lost in the urine.

Under normal circumstances, the renal glomeruli are not permeable to proteins (too large to fit.)

Damage to glomeruli allows large molecules such as proteins to leak out, and kidneys have no mechanism to reclaim them.

QUESTION 15

Why is the belly of someone with liver disease swollen?
How about in malnutrition?

Both are caused by **decreased production of albumin**, leading to hypoalbuminemia.

Decreased BOP increases net filtration pressure, causing ascites (abdominal edema.)

Albumin is produced in the liver, so liver damage will obviously interfere with this.

In protein malnutrition, the body lacks the amino acids necessary to assemble albumin.

(Remember **kwashiorkor**, which we talked about last unit.)

QUESTION 16

How do we explain the signs and symptoms of a nasal allergy?

Sinus drainage triggered by **histamine**, which is released in an attempt to flush out allergens.

Histamine increases **capillary permeability**, making it easier for filtration forces to push water out of circulation and into the epithelium of the sinuses.

QUESTION 17

How does lymph blockage lead to edema? What do we call this type of edema?

Slightly more fluid is pushed out of circulation by filtration forces than is reabsorbed by absorption forces. (Only about 85% re-enters circulation.)

The other 15% is pushed into lymph vessels by the IFHP, along with any large extracellular debris too large to enter the capillaries.

Eventually, after filtration in the lymph nodes, this fluid is dumped back into the subclavian veins.

If the lymphatic system is blocked, that extra fluid has nowhere to go.

Instead, it builds up in the tissue, causing swelling which we call **lymphedema**.

How can we tell the difference?

Many types of edema are **pitting**. When you press on it, IFHP goes up, briefly leaving a small divot or "pit."

Lymphedema is **non-pitting**. If you press on it, the fluid has nowhere to go and it springs right back.

QUESTION 18

How do varicose veins lead to edema?

Both are associated with peripheral venous disease. Incompetent valves in the legs make it harder for venous flow to travel "uphill."

Varices can be a sign of early-stage venous insufficiency, and can later progress to leg edema.

What is the pathophysiology behind this edema?

Impaired venous bloodflow "backs up" into capillaries, increasing CHP and thus net filtration pressure.

More fluid pushed out of capillaries into the tissues, causing swelling of the legs.

QUESTION 19

Give some examples of localized edema.

Very localized: swelling due to an insect bite, bee sting, etc. Root cause is a histamine-mediated inflammatory response.

Remember histamine's effect on **capillary permeability**—makes it easier for fluid to "leak" out of capillaries and into tissue.

Less localized:

- Lymphedema
- Unilateral leg swelling due to deep vein thrombosis (DVT)

QUESTION 20

Describe some therapies that may help in edema.

sequential compression device (SCD) – squeezes on legs intermittently, increasing IFHP to prevent edema

compression stockings – thromboembolism-deterrent (TED) hose, also compression therapy

elevation – raising affected area makes it easier for blood to return to heart, decreasing CHP

QUESTION 21

How does edema lead to damage to tissue?

Excess interstitial fluid pushes cells farther apart, increasing their distance from the capillaries and thus making it harder for them to get required nutrients.

Cells die more easily, potentially resulting in problems such as pressure ulcers.

Increased pressure on tissues can cause other issues depending on location, e.g. in the brain.