Lecture Notes

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PHYSIOLOGY

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019

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Body fluids

- Body fluids are present in two compartments:
  1. Intracellular fluid (inside the cells) → 28 liters
  2. Extracellular fluid (outside the cells) → 14 liters; it's either in the interstitial spaces between the cells → 11 liters or as plasma → 3 liters.

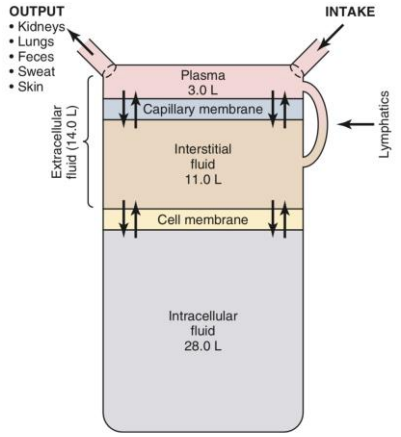


Figure 25-1. Summary of body fluid regulation, including the major body fluid compartments and the membranes that separate these compartments. The values shown are for an average 70-kilogram adult man.

- Meaning that the total fluid volume in the body equals 42 liters = 65% of the total body weight

- This table shows the composition of the extracellular and the intracellular fluid compartments, Notice the following:

COMPOSITION OF EXTRACELLULAR AND INTRACELLULAR FLUID COMPARTMENTS
(values in meq/l unless otherwise indicated)

CONSTITUENTS AND PROPERTIES	EXTRACELLULAR FLUID		INTRACELLULAR FLUID
	PLASMA	INTERSTITIAL FLUID	
Sodium	142	145	10
Potassium	4	4	160
Calcium	5	5	2
Magnesium	2	2	26
Chloride	101	114	3
Sulfate	1	1	20
Bicarbonate	27	31	10
Phosphate	2	2	100
Organic acids	6	7	—
Proteins	16	1	65
Glucose (av)	90 mg%	90 mg%	0–20 mg%
Lipids (av)	0.5 g%	—	—
pH	7.4	7.4	6.7

1. In the extracellular fluid mainly, it contains sodium (Na+), chloride (Cl-) and proteins.
2. There's almost no difference between plasma and the interstitial fluid (same Na+, Cl- and even glucose concentrations, also the same Ph).
3. The difference between plasma and the interstitial fluid is in the protein concentration (it's higher in the plasma compared to the interstitial fluid to produce the colloidal osmotic pressure).
4. When we compare the extracellular fluid with the intracellular we notice that sodium levels are reduced in the intracellular compartment but the k+ is higher the inside cells (a big difference) also sulfate, phosphate and proteins are higher.
5. Intracellular compared to extracellular (proteins concentration is 65 intracellular while it's 16 extracellular).

- This is the distribution of water in various tissues and organs:
  1. The highest percentage is in the blood followed by the kidneys and the least percentage is found in the adipose tissue.
  2. Percent to body weight → skin 18% , muscles 41.7% (about 42 %) , skeleton 15.9%
  3. Liter in 70 kg → skin 9.07 liters , muscles 22.1 liters , blood 4.47 Liters (about 5 liters)

TABLE 16.2
DISTRIBUTION OF WATER IN VARIOUS TISSUES AND ORGANS

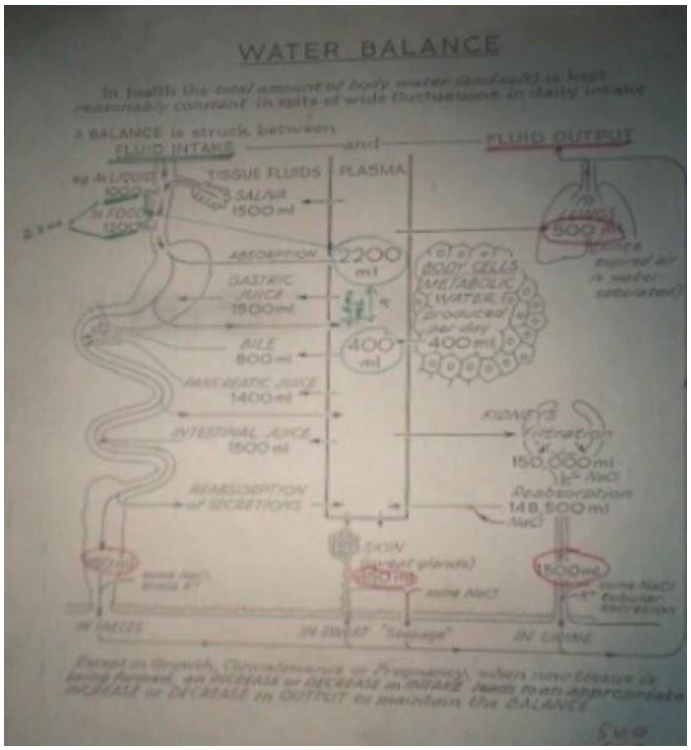
TISSUE/ORGAN	PERCENT WATER	PERCENT BODY WEIGHT	L. IN 70 KG MAN
Skin	72.0	18.0	9.07
Muscle	75.7	41.7	22.10
Skeleton	31.0	15.9	3.45
Brain	74.8	2.0	1.05
Liver	68.3	2.3	1.10
Heart	79.2	0.5	0.28
Lungs	79.0	0.7	0.39
Kidneys	82.7	0.4	0.23
Spleen	75.8	0.2	0.11
Blood	83.0	7.7	4.47
Intestine	74.5	1.8	0.94
Adipose	10.0	9.0	0.63
Total body	62.0	100.0	43.40

- This table shows the total body water in relation to age:
  1. The most significant difference is between the ages 18 and 40 (10 % difference)
  2. There's almost no difference between the ages 10 and 18 (2%)
  3. After the age of 40 this difference starts to decrease slightly (8% difference)
  4. Over the age of 60 the difference is about 6%.

Table 1–3. TBW (as percentage of body weight) in relation to age and sex.*

Age	Male	Female	
10–18	59%	57%	=02 %
18–40	61%	51%	= 10 %
40–60	55%	47%	= 08 %
Over 60	52%	46%	= 06 %

- You can notice the water balance which means that fluid intake should equal fluid output



Fluid intake:

1. 1 L from ingested liquid
2. 1.2 L from food (2.2 liters)
3. 0.4 L from metabolism

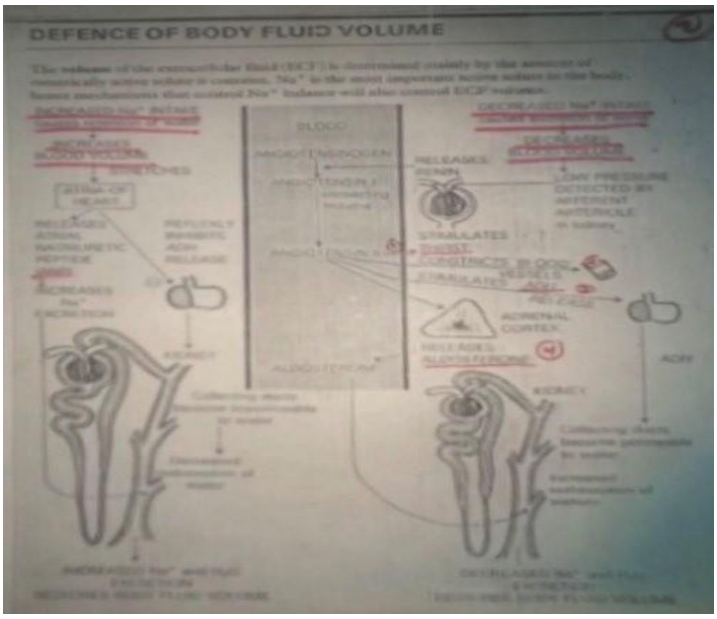
   = 2.6 liters

Fluid output:

1. 0.5L expired through the lungs
2. 1.5L excreted as urine
3. 0.45L through the skin (sweat)
4. 0.15L through the stool

   =2.6 liters

Defense of body fluid volume



When:

- Na+ intake increases:
  1. Retention of water
  2. Blood volume increases
  3. When the atria of the heart stretches it releases the atrial natriuretic peptide (ANP).
  4. Increases Na+ excretion
  5. Reflexly ADH release is inhibited
  6. As a result, water and Na+ excretion will increase to restore body fluid volume.

- Na+ intake decreases:
  1. Will cause water excretion
  2. Blood volume decreases
  3. Low pressure detected by the afferent arteriole in kidney
  4. Renin is released from the kidney which converts angiotensinogen to angiotensin 1 → will be converted to angiotensin 2 under the effect of a converting enzyme in the lungs

Functions of angiotensin 2:

1. Thirst
2. Constriction of the vessels
3. Stimulates ADH and stimulates aldosterone secretion from the adrenal cortex which will decrease water and Na+ excretion to restore the body fluid volume.

Dehydration

- If the hemodynamic mechanisms fail to operate properly loss of water or electrolytes or both may occur.
- Three conditions may arise depending on the relative loss of fluid and electrolytes:
  1. isotonic dehydration: equal loss of fluid and electrolytes, osmotic pressure is within normal limits, total ECF volume changes.
  2. hypertonic dehydration: excessive fluid loss compared to electrolytes, water thus tends to move outside the cells (concentrated ECF)
  3. hypotonic dehydration: excessive electrolytes loss compared to fluid, water thus tend to enter the cells (diluted ECF).

- Clinical dehydration may be a consequence of:
  1. Failure of absorption from the alimentary tract (as in pyloric stenosis or high Intestinal obstruction).
  2. Excessive loss from copious sweating, prolonged vomiting, diarrhea and excessive diuresis.
  3. Drainage from wounds or burns.

Hydration (water intoxication)

- HYDRATION is a term referring to the results of:
  1. Excessive water intake
  2. Decreased loss of water
  3. Increased reabsorption of water from the kidney because of ADH administration. In such a case, the excess water is evenly distributed in both the ECF and ICF compartments, causing an increased water volume, with dilution of solutes in both areas.

- Excessive water intake may produce the syndrome of Water intoxication:
  1. in which cellular function is disturbed by the dilution of cellular electrolytes.
  2. Disorientation, convulsions, and coma may result.
  3. as well as gastrointestinal dysfunction, muscular weakness, and abnormal cardiac rhythms.

The lymphatic system

- In the arterial end, the blood pressure is 32 mmHg and the colloidal pressure is 28 mmHg.There is a pressure that pushes the plasma to be filtrated from capillaries into interstitial spaces so plasma is filtered containing little proteins.
- At the venous end, the opposite happens; blood pressure decreases but plasma protein pressure doesn't change so there is osmosis but plasma isn'tretained fully to the venous end, little plasma remains with little proteins.
- This remaining fluid is called lymph → it passes into the lymphatic system.

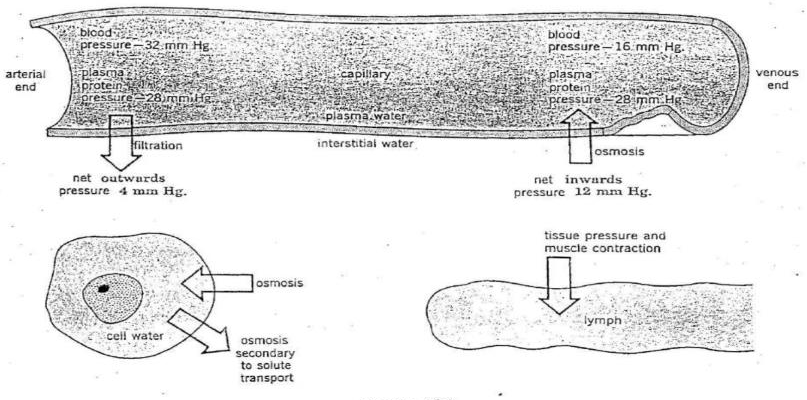


FIGURE 16.3
Some determinants of water movement between body water compartments.

- The lymphatic system represents an accessory route through which fluid can flow from the interstitial spaces into the blood. Lymph is tissue fluid that enters the lymphatic vessels. It drains into the venous blood via the thoracic and right Lymphatic ducts.
- It contains clotting factors and clots on standing in vitro.
- In most locations, it also contains proteins that traverse the capillary walls and return to the blood via the lymph. Its protein content is generally lower than that of plasma, which contains about 7 g/dL, but lymph protein content varies with the region from which the lymph drains.
- Water-insoluble fats are absorbed from the intestine into the lymphatics, and the lymph in the thoracic duct after a meal is milky because of its high fat content.
- Lymphocytes enter the circulation principally through the lymphatics, and these are appreciable numbers of lymphocytes in thoracic duct lymph
- Components of the lymphatic system:
  1. lymphatic capillaries
  2. lymphatic vessels
  3. lymphatic nodes
  4. lymphatic ducts
- Related organs: Three organs are closely related to the lymphatic system which are the spleen, tonsils, and thymus. All of these organs are composed largely of lymphoid tissue, a specialized form of connective tissue characterized by a framework of reticular tissue and the presence of lymphocytes.
- Tissues that lack lymphatic capillaries include
  1. Avascular tissues: such as cartilage, the epidermis, and the cornea of the eye
  2. Central nervous system
  3. Portions of the spleen
  4. Bone marrow
- Flow of lymph
  Lymph, like venous blood, is under relatively low pressure and may not flow readily through the lymphatic vessels without the aid of outside forces. These forces include:
  1. Contraction of skeletal muscles
  2. Pressure changes due to the action of breathing muscles
  3. Contraction of smooth muscles in the walls of larger lymphatic vessels.
- Functions of the lymphatic system:
  1. Return of excess filtered fluid
  2. Defense against disease: The lymph percolates through lymph nodes located in route within the lymphatic system. Passage of this fluid through the lymph nodes is an important aspect of the body's defense mechanism against disease. For example, bacteria picked up from the interstitial fluid are destroyed by special phagocytic cells located within the lymph nodes.
  3. Transport of absorbed fat
  4. Return of filtered protein

- **From Slides**: Importance of lymph flow: It has been estimated from studies in dogs with radioactively labeled plasma proteins that in one day 50 per cent or more of the total plasma protein is lost from the capillaries and returned to the blood stream by the lymphatic circulation. Furthermore, the amount of fluid filtered from the capillaries is greater than the amount reabsorbed. Inadequate lymph drainage can lead to an excessive accumulation of fluid in the interstitial space, a condition called edema. Some lymphedemas (edemas resulting from deficient lymph drainage) can cause gross disfiguring. An example is elephantiasis, a specific lymphedema resulting from blockage of lymph vessels. In a form of elephantiasis common in the tropics, the blockage follows invasion by a parasitic roundworm (filaria).

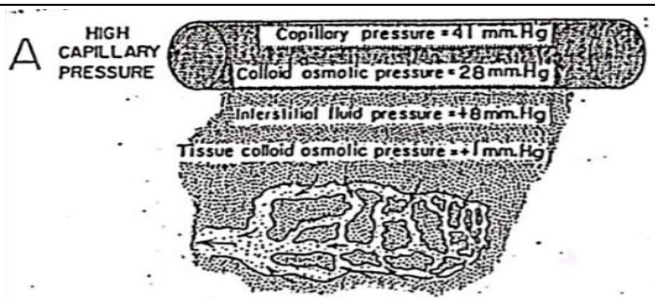
Edema

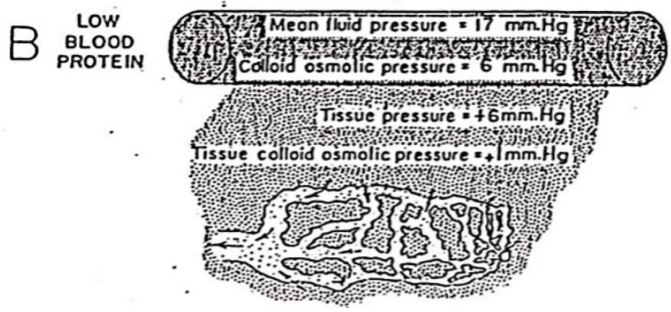
- A condition caused by accumulation of fluid primarily in the intestinal compartment.

Main causes of edema:

1. High capillary pressure: A lot of fluid is filtered from the capillaries into the interstitial spaces, and not all of this fluid returns back in the venous end

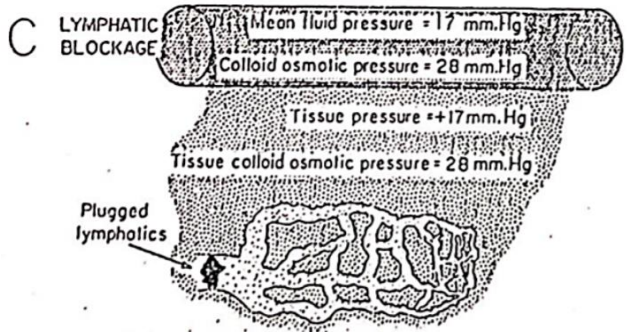
2. Low blood protein: not all of the filtered fluid returns back to the veins

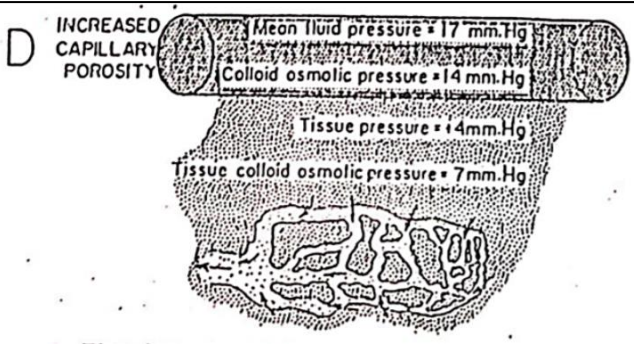




3. Lymphatic blockage

4. Increased capillary porosity: similar to high capillary pressure





- **From Slides**: causes of edema:

1. Increased blood hydrostatic pressure in capillaries due to an increase in venous pressure. This may result from poor blood flow back to the heart due to cardiac failure or blood clots.
2. Decreased concentration of plasma proteins, which lowers blood colloid osmotic pressure. Protein loss may result from burns, malnutrition, liver disease, and kidney disease.
3. Increased permeability of capillaries, which raises interstitial fluid osmotic pressure by allowing greater amounts of plasma proteins to leave the blood and enter tissue fluid. This may be caused by chemical, bacterial, thermal, or mechanical agents.
4. Increased extracellular fluid volume as a result of fluid reten-tion. When a person has difficulty excreting fluids, for what-ever reason, but continues to drink normal amounts of water, extracellular fluid in the body increases. Some of the fluid enters blood and increases blood hydrostatic pressure.
5. Blockage of lymphatic vessels as often occurs after a radical mastectomy (breast removal, usually because of cancer) or in-fection by filariasis roundworms. In a radical mastectomy, nearby lymph nodes that appear cancerous are removed with the breast tissue. Edema occurs in the arm on the same side because lymph drainage is blocked. The larvae of the tropical filariasis parasite invade and block lymphatic channels, causing the I grossly disfiguring type of edema known as elephantiasis

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