Physiology Notes

9/21/05

Urinary System

Blood pressure in the glomerulus: Because the diameter of the afferent arteriole going to the glomerulus is 25% larger than normal, the pressure exerted on the glomerulus is greatly increased, up to four times. This permits the free flow of water and soluble This permits the free flow of water and soluble materials our of the glomerulus and into the Bowman's capsule and the tubes of the nephron.

What stays and what goes:

- What can't get out – blood cells, large proteins
- Everything else can get out.

Definitions:

- **Glomerular filtration** – the process of filtering the blood.
- **Glomerular filtrate** – the substance that gets filtered out into the tubular system.
- **Urine –** the final product that makes it out of the body. (The glomerular filtrate that is left at the end of everything...)
  - Amount of urine excretion = filtration rate – reabsorption rate + secretion rate
- **Tubular reabsorption** – movement of material out of the tubules out to the interstitial space and then back into the periItubular capillaries.
- **Tubular secretion** – movement of material from the capillaries to the tubes of the nephron.

Volumes:

- Up to 180 liters of filtrate are formed in a 24 hour period.
- Only 1 to 2 liters of urine

Blood Flow to Kidneys:

- **Renal blood flow:** 21% of cardiac output.
- **Kidney vs Body weight:** 0.5% to 1% of body weight.

Autoregulation:

- **Autoregulation:** The blood pressure and amount of blood being filtered by the kidneys remains fairly constant thru a process called **autoregulation.**
- **Juxtaglomerular appratus –** region of ascending loop of henle. There is a place on the ascending loop that touches the afferent arteriole. The main area for autoregulation of the

kidneys.

- **Afferent arteriole** – carries blood to the nephron.
- **Macula densa cells** – where the loope of Henle meets the afferent arterioloe, the cells in the loop have been modified.
- **Juxtaglomerular cells** found in the afferent arteriole
- **The area where these two types of cells meet** – juxtaglomerular apparatus.
- **Macular densa** – have the capability of monitoring the sodium chloride levels in the blood
- **Juxta glomerular cells** – can produce an enzyme called **renin** that influences blood pressure.

Urine Production

- Kidney filter 1200ml blood per minute. Remove about 19% of blood plasma per minute.
- What does not get filtered out – cells and proteins.
- The net filtration rate in a normal nephron is 10mm/Hg
- Tubular reabsorption – where most of the fluid and much of the dissolved substances leaves the tubules and reenters the blood.
- Where do most of the fluids and much of the dissolved substances reenter the blood – at the peritubular capillaries.
- Only 1% of the filtered fluid is released as urine.
- **Where is most of the water reabsorbed –** at the beginning of the proximal tubule
- Glucose and AA – towards the end of the proximal convoluted tubule.
- Na and Cl – through the entire length.
- ADH – works at the level of the collecting duct (more or less)
- Water leaves the tubules by osmosis.
- Solutes require active transport or facilitated diffusion.
- **Renal threshold** -every kidney will have a specific level at which glucose will be reabsorbed. Anything above that and it will be excreted. **The upper limit of sugar in the tubules above which sugar cannot be reabsorbed out of the tubules. (there's a fair amount of variation between people).**
- **Renal diabetes** – normal blood glucose levels but it spills into the urine because there are not enough carrier molecules to catch and save the glucose.
- **Intercellular fluid –** around the parts of the nephrons vary in concentration of solutes in different areas of the kidney. This variation has a lot to do with the movement of water and dissolved substances out of the tubules.
- **Tubular Secretion** – transport of ions and molecules into the tubules.

Blood pressure, volume and concentration are controlled by the kidney

Aldosterone – hormone from the adrenal cortex.

- Causes sodium to be reabsorbed into the peritubular capillaries. This will cause water to follow which decreases urine output and increases blood pressure. (It functions to raise blood pressure)

Anti diuretic hormone

- secreted by the posterior pituitary gland
- causes the distal convoluted tubules and collecting ducts to become more permeable to water. This will cause more water to be reabsorbed and decrease urine output. This will increase Blood pressure.

Atrial natriuric hormone – produce in the heart

- produced by the atrial cells of the heart when they are stretched.
- This stretching happens with extra quantities of blood at high pressure.
- It increases urine output and lowers blood pressure.

Renin – Angiotensin – Aldosterone Mechanism

- **Renin** is an enzyme produces by the juxtaglomerular cells (ascending loop of henle) in response to low blood pressure or decreased blood sodium level. It interacts with angiotensin and winds up with angiotensin II.
- **Angiotensin**
  - Acts on renal tubules of the kidney to cause increased Na reaborption.
  - Works on the adrenal cortex to increase aldosteron production which also causes increased sodium retention.
- **Renin-angiotensin-aldosterone mechanism**... - This increases blood pressure.
- **Angiotensin** is already there. It's precirculating.

Urine

- **Micturation** - the expelling of urine from the bladder.
- **Maximum volume of a full bladder** – 1 liter.
- **Micturation reflex** – volume at which the average patient feels the need to void 200 – 400 ml.
- **Detrusor muscles** – stretch receptors in the bladder initiate a reflex in the spinal cord which then travels back to the detrusor muscles of the bladder via parasympathetic nerves.
- **Urinary Incontinence** – inability to control and properly release urine from the bladder.

Urine Composition

- Urine is: In General 95% water and 5% solutes.
- *Albumin – one of the lightest proteins. (test questions about albumin)*
- Fluids comprise 60% of body weight, the other 40% is comprised of solids.
- Age vs % of water. - Babies are 70-75% water. Old age may be only 40% water.

Fluid compartments

- Intracellular fluid is 40% of body weight
- Extra cellular fluid is 20% of body weight

  Extra cellular fluid is blood plasma and interstitial fluid

    - Interstitial fluid – 15%
    - Plasma is 5%.

Edema – interstitial fluids increased.

Fluid Intake/Output

Intake of fluid should equal output of fluids which on average is 2.5 liters.

Explain – we micturate 1.5, the rest is feces, perspriation...

Intake:

- Beverages: 1600
- Metabolic water 200ml
- Food 700 ml.

Electrolytes

Electrolytes – elements, compounds or molecules that carry a charge.

Normal extracellular electrolytes include: NA+ (cation), CL- (anion), Bicarbonate Ion (HCO3-)

Intracellular ions: potassium(k)+, Phosphorus-

The body tends to move positive ions: The negative follows.

Aldosterone from the renal cortex is the primary hormone regulating sodium and potassium concentrations at the kidney tubules.

Edema – Too much sodium ions in the extracellular fluids causing a movement of water out of the cells.

pH

Normal blood pH – 7.35 to 7.45

Alkalosis – pH above 7.45

Acidosis – pH below 7.35

pH control:

1. Buffers – a substance that can combine with hydrogen ions(acids) to raise pH or release h ions(acid) to lower pH.
2. Removal of CO2 by the lungs. CO2 is a byproduct of normal cellular respiration. (Carbonic acid)
3. removal of H ions by the kidney. Mechanisms for the tubules to remove H ions when the body

is too acidic.

Review for Final

GI Tract

- Function of nerve plexus and names (2q's)

The intestinal tract has it's own enteric nervous system just as the heart has its' own nervous system. There are two sets of nerves. Their jobs are to integrate and coordinate the motility, secretory, and endocrine functions of the GI tract.

- Submucosal plexus (aka Meissner's plexus) - secretion/absorption/flow of blood.
- Myenteric plexus (aka Auerbach's plexus) - Motility – the outer layer of muscles. Long and circular muscles. The myenteric is the more superficial of the two.

- Function of 4 major gi tract hormones from class (3q's)

Gastrin is a hormone secreted in response to small peptides and AA in the stomach and stretching of the stomach. (More acid)

- Increase H+ secretion by gastric parietal cells (increase acidity of the stomach) By causing gastric parietal cells to make acid. (The major cell in the stomach that produces acid – parietal cells)
- Stimulates the growth of the gastric mucosa.

Cholecystokinin (CCK) Again stimulated by the presence of small peptides/AA and the presence of fatty acids. (More bile)

- Stimulates the gall bladder and relaxes the sphincter of Oddi
- Stilumates the pancrease to release of digestive enzymes
- Stimulates growth of the exocrine pancreas
- Inhibits gastric emptying which means it tells the stomach to work on the material a little longer.

Secritin is stimulated by the presence of H+ in the duodenum and fatty acids in the duodenum. (More bicarb)

- Stimulates the pancreas to secrete bicarbonate (a base) also stimulates pancreatic growth
- Stimulates the liver into secreting more H2O and bicarbonate, and increases bile production.
- Inhibits H+ secretion by the gastric parietal cells

Gastric Inhibitory Peptide (GIP) which is the only one of the four that is stimulated by the presesence of not only AA, FA's and peptides, but also the presence of carbohydrates. (More insulin)

- Stimulates insulin release by the pancreas
- Inhibits H+ production by the gastric parietal cells

Endocrine

- Know the hormones from class, their origin, and the target or function (?q's)

Anterior Pituitary

Somatotrophes

- **Secrete** growth hormone.

- **Volume wise** – the number one pituitary hormone.
- **Function** – stimulates the growth of all body tissue. (also stimulates nerve tissue) Continues to be secrete throughout life.
- **Conditions:**
    - **Dwarfism** – lack of height due to a deficiency of growth hormone in childhood.
    - **Gigantism** – An excess of height due to excess growth hormone in childhood.
    - **Acromegaly** – Production of excessive amounts of growth hormone after the growth plates of the long bones have ossified. This results in a widening of the bones rather than length. (Ed Sullivan, Richard Boone, Andre the Giant, etc

Thyrotrophs

- **Secrete** – TSH (Thyroid Stimulating Hormone)Thyrotropin
- **Function** – cause the thyroid to secrete thyroid hormone which increases the bodies metabolic rate
- **Conditions**
    - **Creatinism** – A dwarf that is due to a lack of TSH instead of Growth hormone.
    - **Graves Disease** – a type of hyperthyroidism

Corticotrophes

- **Secrete** – adrenocorticotrophic hormone (ACTH)
- **Function** – reacts with the cortex of the adrenal gland to secret adrenal hormones (mostly – cortisol)
- **Conditions**
    - **Addison's Disease** – associated with hyposecretion of the adrenal cortex.
        - **Cushing's Disease –** associated with hypersecretion of the adrenal cortex. (Adrenal glands - cortex – stimulated by hormones, medulla by autonomic nervous systems)

Gonadotrophes

- **Secrete** Follicle Stimulating Hormone (FSH)
    - **Function** stimulates the production of egss or sperm cells.
    - **Condition**
        - Hyposecretion – retards the production of eggs or sperm.
- **Secrete** Leuteinizing Hormone - LH is also called interstitial cell-stimulating (ICSH) hormone in men.
    - **Functions** - stimulates ovulation of eggs in women and the production of testosterone in men.
    - **Conditions**
        - Hypo secretion – retards the maturation of eggs.
        - Precoius syndrome – onset of puberty earlier than normal (used to be 10)

Mammotrophes

- **Secrete** prolactin (lactogenic hormone)
- **Function** – stimulates the development of glandualar breast tissue during preganacy and the production of milk after birth.
- **Condition**
  - Hypo secretion – causes no problems other than the inability to breast feed. Hypersecretion is generally related to a pituitary tumor and causes inappropriate lactation, lack of menstruation, etc. In males it results in impotence.

Posterior Pituitary Lobe

Consists of – cells called pituicuytes.

Secretes:

- **Oxytocin** – contraction of smooth muscles in the walls of the uterus in birth. (what gives the push) it also stimulates the breasts to eject milk.
- **Antidiuretic hormone (ADH)** – promotes the retention of fluids by the kidney.

Conditions

- **Diabetes insipidus** – too little ADH

Pineal Gland

Location: toward the back of the brain

Secretes:

- Melatonin – the control of the circadian rhythm. (24h cycle of the body) (temp and BP run highest in the evening) (MD's say this is a landmark for xrays. It calcifies as we turn older.)

Thyroid

Located – In the throat anterior to the lower portion of the thyroid cartilage. (in lay terms, the Adam's apple) It's a double lobed thing. Test both sides.

Produces:

- **Thyroxine** – (T4) – Most abundant of hormones that speed up metabolism, but less active. Is converted to t3.
- **Triioodothyronine** (T3) – produced in smaller quantities, but the more active form. Speeds us up.
- **Thyrocalcitonin** (or just calcitonin) Deals with calcium levels in the blood. Lowers calcium blood levels by moving it into the bones.

Actions:

- T3 T4 increase in metabolic activity
- Thyrocalcitonin has at its function the lowering of calcium levels.

Other Names:

- T7 hormone is a combination of T4 and T3.
- Thyroid hormone also means T4 and T3.

Iodine:

- The trace element iodine is necessary for the production of T7
- but not thyrocalcitonin.

T7 is carried through the body: bound to a protein called Thyroid Binding Globulin (TBG). Only a small amount is active and flowing freely in the blood. The TBG takes it to the cells where it then becomes active.

Hyperthyroidism

- any condition where the thyroid gland is producing excess thyroid hormone.
- The most commonly noticed system is the bug-eyed appearance of the patient This is called exopthalamos.
- Hyperthyroidism is a decrease in T7 production. T3/T4 is controlled by TSH negative feedback. Low T7 stimulates TSH, High T7 levels inhibits TSH.

Goiter

- low levels of iodine, will increase the number and size of thyroid cells. Guess what, an increase in the amount of iodine causes the same size problems.

Parathyroid Gland

Location: Four small glands embedded onto the surface of the thyroid gland. (On the back side)

Secretes: Parathyroid hormone (PTH) which increases blood calcium levels

Normal calcium blood levels are 8.5 to 10.5 mg/dl

Low blood calcium levels cause parathyroid hormone production which causes the release of calcium from the bones.

High blood calcium levels cause decrease parathyroid hormone production and also cause an increase in thyrocalcitonin.

Calcium/Magnesium Relationship: There is a direct calcium/Mg relation ship.

Calcium/Phosphorus Relationship: an inverse CA/P relationship.

A change, up or down, in either Ca or Mg – tends to be mirrored by the other.

PTH regulates: Ca excretion/secretion at the level of the kidney. Meaning it will influence the kidney to retain or secrete Ca as needed to maintain proper blood levels.

The two main substances that will raise blood Ca levels are - PTH and Vitamin D

Blood calcium levels are lowered by thyrocalcitonin.

You can live without: the thyroid gland, you cannot live without the parathyroid glands.

Adrenal Glands (Cortex)

Outer cortex – three distinct cell layers (electrolyte balance)

Outer Layers

Produces: Mineralocorticoids

Function – regulate electrolyte and water level balance. By promoting the absorption of sodium and the secretion of potassium by the kidneys.

The major one is Aldosterone.

Middle Zone:

Produces: Glucocorticoids in the middle zone. (glucose balance – raises glucose by decrease glucose metabolism).

Function to raise glucose levels by decreasing glucose metabolism.

The major one is: (cortisol – the major Glucocorticoid.)

Inner Layer

Produces: also secretes Glucocorticoids plus some sex hormones (almost negligible)

The above three: all come under the heading of steroids.

Adrenal Glands (Medulla)

Inner medulla

Produces: Epinephrine and Norepinephrine.

Functions: These two hormones effects the sympathetic nervous system.

Pancreas

Produces: digestive enzymes and hormones.

Islets of Langerhans - Three types of cells found here.

- **Alpha cells** (20% of island cells)
  - Produces: Glucagon
  - Functions: which raising blood sugar levels by converting glycogen into glucose.
- **Beta cells (70% of islet cells)**
  - **Produces:** Insulin
  - **Functions:** lowering blood glucose levels by speeding up glucose absorption into the cells. (via facilitated diffusion)
- **Delta cells** (5% of cells)
  - **Produces:** Somatostanin
  - **Functions:** lowers insulin production and increases Glucagon production.

The only one we cannot live without: is insulin.

Gonads

Male and Female gonads: Testes and Ovaries

Male gonads secrete – testosterone – producing secondary sexual characteristics, enhances the sex drive

Female gonads secrete – Estrogen – produced secondary sex characteristics. Female sex drive apparently from androgens in the adrenal cortex.

Lymphatic

- Know general difference between T and B lymphocytes (2q's)
  - Lymphocytes are "born" in red bone marrow as are all blood cells. While they are born in the bones, they mature in at least two different locations. Some of the lymphocytes migrate to the thymus gland and are called T-lymphocytes. Or more correctly – Thymus dependent lymphocytes.
  - The lymphs that mature in the "bone marrow" are called B-lymphocytes or bone marrow dependent lymphocytes.
  - Both B and T cells are circulating in the blood and lymph systems: 70% are T-cells, 30% are B-cells.
  - There is also a small number of lymphocytes are called null cells. Their function is to destroy tumor cells.

Lymph nodes contain an outer cortex and inner medulla

- Superficial portion of the cortex – mostly B-cells
- Deeper portion of the cortex – Mostly T-cells

Antibody response:

- B- cells make antbodies.
- T-cells go out and fight directly

- Know what other white blood cell is that is important in working with lymphocytes in specific immunity and what it does (1q)

  Explanation – the first time a b or t cells meets an antigen, there's not that many of them. So not much happens. So, they are taken care of by the macrophages or neutrophils. The next time it comes around is when the T or B cells are ready to fight with the antibody response. It's only limited the first time.

  Memory cells are T or B cells that have been sensitized to the antigen and have the capability of rapid proliferation of either T cells or production of antibodies.

  Quick review of speciific immunity:

  1. Invasion – a foreign material enters he body and the body recognizes it as an antigen.
  2. That specific antigen is an antigen because of some unique chemical formation that's large enough to be recognized by the lymph cells.
  3. Macrophages ingest the foreign material and then
     a. Digest it.
     b. separate the specific antigenic material that's going to be present to the lymphocytes.
  4. the lymphocytes then reacts to the antigen and does it's specific thing.

- Define the terms antigen, antibody (2q's)

  Antigen – a substance foreign to the body that causes a reaction by the body to that one specific antigen.

  Antibody – a substance produced by the body (specifically by a B lymphocyte) that will attack and destroy that one particular antigen, but no other antigen.

- Distinguish between cell mediated and humoral immunity. (2q's)

  Cell mediated immunity

  - Carried out by – t cells
  - Macrophages present digested antigen – to the t cell
  - The T-cells now recognize the material as an antigen and – and take the fight directly to the antigen

  Humoral immunity

  - carried out by – b-cells
  - macrophages present digested antigen – to the b-cell
  - The b cells now recognize the material as an antigen and – turn into plasma cells and produces antibodies to combat the antigen.

- Know the difference between CD4 and CD8 lymphocytes (2q's)

  T lymphocytes are classified into two major groups based on specific antigens found on their surfaces. They are called CD4 and CD8 cells.

  - CD4 cells – these are the t-helper cells and make up 70% of the T-cells.
    - A lack of CD4 cells leads to (as in AIDS) diminished immune response. (AIDS – the HIV virus attacks primarily the CD4 cells)
  - CD8 cells – these are the suppressor and toxic t cells and make up 30% of the t-cells.
    - A lack of CD8 cells leads to things like autoimmune disease, because the immune system is out of control.

- Know the five immunoglobulin by description, function, or percentage. (5q's)

IgG

1. most abundant 75%
2. found in blood and lymph.
3. monomere, one unit,
4. major antibody produces on the second exposure to the antibody.
5. Only antibody to pass through the placenta. (this is a function of the handles)
6. Triggers the compliemnt system – function of the handle.

IgA

1. dimer – two units
2. makes up about 15% of the antibodies
3. found in body fluids (tears, urine, snot, mucous) – provides localized protectice resistance on areas of mucous membrane. (Reduced in times of stress. (you also dry up when you sleep... this is much like Wei Qi!)) (It's on the surface...)
4. Present in mothers milk – second form of passive immunity given to the infant.

IgM -

1. the largest
2. pentamers – there are five units
3. first antibody to be secreted by a plasma cells after an initial exposure to an antigen.
4. Agglutinate and lysis of bacteria. Significance – between viruses and bacteria. Bacteria are most likely to reproduce quickly.
5. Makes up about 10% of the immunoglobulins.
6. This is traveling in blood and lymph fluid.

IgE

1. less than 0.1% of immunoglobulins
2. found on the surfaces of mast cells and basophiles and involved with allergic reactions.

IgD

1. makes up less than 1%
2. least understood of he immunoglobulins. Believed to be invoved with the activation o B lymphocytes.

Five questions from tonight's lecture.

- Tubular reabsorption and tubular secretion 2 q
  - **Tubular reabsorption** – movement of material out of the tubules out to the interstitial space and then back into the periItubular capillaries.
  - **Tubular secretion** – movement of material from the capillaries to the tubes of the nephron.
- What goes into autoregulation (Juxtraglamarular apparatus – understand it) 1 q

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- **Renin-angiotensin-aldosterone mechanism**... - This increases blood pressure.
  - **Angiotensin** is already there. It's precirculating.

- Know the function of the hormones that play a major function in blood pressure in the kidneys (pg 90) 3q's

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