**Lab 7:** The Urinary System

***Introduction.*** The Urinary system consists of the kidneys, where urine production occurs, and the conducting system that transports and stores urine before elimination from the body. The conducting system is the ureters, urinary bladder, and urethra. The kidney performs important functions necessary to remove nitrogenous wastes and maintain homeostasis, but problems with the kidneys or conducting system (ureter, urethra) can have a direct effect on renal function.

***Objectives***

1. Learn the anatomical characteristics of the kidney and the accessory organs.
2. Learn nephron anatomy and the function of each segment.
3. Understand the process of urine formation with reference to the anatomical structures.
4. Understand renal physiology terms excretion, elimination, reabsorption, secretion, filtration and how each relates to formation of urine.
5. Conduct a urinalysis, and understand how to diagnose patients with abnormal test results.
6. Learn the composition of normal urine and compare this to plasma.
7. Learn the relationship between the endocrine system and urinary system (RAAS).
8. Always, lab math!

***(1) Anatomy of the Urinary System***

***Tasks***

1. Learn the relevant anatomy using the models in the lab and your textbook. Please keep in mind the general “functions” of each.
2. Review the “Basic” formation of urine.
3. Understand the pathway urine takes, form the glomerulus to the urtethra!
4. Work together as a class answering EOL questions

🡪 *Urinary System Organs*

1. Kidneys

*“Urinary tract”*

1. Ureters
2. Urinary bladder
   * Detrusormuscle
3. Urethra

🡪 *Associated Structures of the Kidneys*

1. Adrenal gland
2. Adipose tissue

🡪 *Kidney Gross Anatomy*

Fibrous capsule

Renal hilum

Renal cortex

Renal medulla

Renal pyramids

Renal papilla

Renal pelvis

Major calyx

Minor calyx

**🡪 *Nephron***: functional unit of the kidney, consists of renal corpuscle & renal tubule

*Types*

Juxtamedullary nephron

Cortical nephron

*Renal corpuscle*

1. Glomerular (Bowman’s) capsule
   1. Capsular outer layer
   2. Visceral layer (formed by podocytes)
      1. Filtration slits
2. Glomerulus

* Capsular space

*Renal tubule*

Proximal convoluted tubule

Distal convoluted tubule

Loop of Henle (Nephron loop)

Descending limb

Ascending limb

*Filtration membrane*

1. Fenestrated endothelium
2. Basement membrane (Dense layer)
3. Foot processes of Podocytes (Pedicels)

*Juxtaglomerular Apparatus* *(Complex)*

1. Macula densa
2. Mesangial cells (Extraglomerular)
3. Juxtaglomerular cells

*Collecting System*

1. Collecting duct

🡪 *Histology*:What type of epithelium lines the following…

* Proximal convoluted tubule: simple cuboidal with microvilli
* Distal convoluted tubule: simple cuboidal
* Descending limb (of nephron loop): simple squamous & simple cuboidal
* Ascending limb (of nephron loop): simple squamous & simple cuboidal

🡪 *Vasculature*

1. Renal arteries
2. Renal veins
3. Afferent arteriole
4. Glomerulus
5. Efferent arteriole
6. Peritubular capillaries
7. Vasa recta

🡪 *Basic Formation of Urine (Pg. 987- 989)*

**Processes**

1. Filtration
2. Reabsorption
3. Secretion
4. Excretion
5. Elimination
6. Transport maximum (Tm), renal threshold

**Fluids**

1. Filtrate
2. Tubular fluid
3. Peritubular fluid
4. Urine

***🡪 Questions***

1. Describe the **general** blood flow in the kidney, beginning with the renal artery and ending with the renal vein.

Renal artery 🡪 afferent arteriole 🡪 glomerulus 🡪 efferent arteriole 🡪 peritubular capillaries 🡪 renal vein

1. What are the physiological functions for the glomerulus, vasa recta, and the peritubular capillaries?

* *The glomerulus is a ‘tuft’ of capillaries and filtration through glomerular capillaries produces filtrate. This is the very start of urine formation.*
* *The vasa recta are capillaries that reabsorb fluid from the juxtamedullary (deep) nephrons. Not all nephrons have vase recta! Juxtamedullary nephrons* ***are important for establishing a concentration gradient in your kidneys which allows you to produce concentrated urine.***
* *Peritubular capillaries reabsorb tubular fluid – mostly around cortical nephrons.*

1. Draw a nephron and label each segment. Also, indicate where the following processes occur:
   1. Filtration
   2. **Water reabsorption
   3. Na+ & Cl- reabsorption
   4. Glucose reabsorption
   5. Secretion

*Filtration = water and solute movement across the glomerular capillaries into the nephron at Bowman’s capsule. Reabsorption is movement of water/solutes from the tubular fluid in the nephron to the peritubular fluid (which will ultimately get picked up by peritubular capillaries). Secretion is the opposite of reabsorption; it is movement from the peritubular fluid into the tubular fluid in the nephron.*

1. Outline the pathway for urine formation, excretion, and elimination. Begin at the glomerulus and end at the urethra – using the urine flow cards provided.

Glomerulus 🡪 glomerular capsule 🡪 proximal convoluted tubule 🡪 descending limb (of nephron loop) 🡪 ascending limb (of nephron loop) 🡪 distal convoluted tubule 🡪 collecting duct 🡪 papillary duct 🡪 minor calyx 🡪 major calyx 🡪 renal pelvis 🡪 ureter 🡪 urinary bladder 🡪 urethra 🡪 toilet!

***(2) Urinalysis***

The kidneys form urine as a byproduct of maintaining homeostasis in the body. Urine consists of mainly water (>90%), but also includes excess salts and nitrogenous wastes from blood. Important mechanisms of urine formation include (1) **filtration** at the renal corpuscle, (2) **reabsorption** at the PCT and DCT, and (3) **secretion** at the DCT in the nephron.

Urine has variable concentration of solutes, pH and volume. Urine composition reflects the state of the body and this is something you must understand. Reference the ‘normal’ urine values and consider how the values change during dehydration or over hydration.

***Tasks***

1. Complete the table using your personal “estimates” for urine composition under the provided conditions, and understand that there are wide variations in urine composition.
2. Perform the urinalysis. Understand clinical conditions that may result in altered urine composition. For example, why would protein or red blood cells be found in the urine?

|  |  |  |  |
| --- | --- | --- | --- |
|  | Normal values | Dehydration | Over hydration |
| pH | **4.5 - 8** |  |  |
| Specific gravity | **1.003 – 1.030** |  |  |
| Osmolarity | **855 – 1335 mOsm/L** |  |  |
| Volume | **200 – 2000 ml/day** |  |  |
| Color | **Clear yellow** |  |  |
| Odor | **Ammonia** |  |  |
| Bacterial content | **None (sterile)** |  |  |
| Protein | **0** |  |  |
| Nitrite | **0mg/dl** |  |  |
| Erythrocytes | **0** |  |  |
| Urobilinogen | **125µg/dl** |  |  |
| Bilirubin | **20µg/dl** | PLASMA Values |  |
| Glucose | **9µg/dl** | **70-100 mg/dl** |  |
| Na+ | **333mg/dl (≈58mM)** | **135 -145 mM** |  |
| K+ | **166mg/dl (≈22.4 mM)** | **3.5 - 5.5 mM** |  |
| Amino acids | **287.5µg/dl** | **40 mg/dl** |  |
| Lipids | **1.6µg/dl** | **450-1000 mg/dl** |  |

**🡪 Urinalysis**. Use test strips to measure the urine composition of your own urine! FOLLOW THE DIRECTIONS CAREFULLY! This is a time sensitive experiment.

\*\* See Urinalysis (dip stick) handout

***(3) Physiological Controls of the Urinary System***

The kidneys receive ≈20% of total cardiac output (5L/min), about 1.25 L/min. Roughly 10% of this fluid becomes filtrate, or 125 ml/min. This is a huge volume! The glomerular filtration rate (GFR) is controlled by autoregulation, hormones, including renin and the naturetic peptides, as well as the sympathetic nervous system.

***🡪 Endocrine System & The Kidney*** *these questions are the things you should know when you study the endocrine system. I like to use a table and this is included. These will be a major focus for the end of lab quiz.*

*General Endocrine Questions:* Whenever you learn about a hormone there are several basic question:

1. Where is it secreted?
2. Where does it act?
3. What are the effects?
4. What stimulates its release?

\*\* **See chart below to help you!!!\*\***

Renin: What is the overall purpose or function of this hormone? Is it secreted when blood pressure is high, or low?

Natriuretic peptides: What is the overall purpose or function of this hormone? Is it secreted when blood pressure is high or low?

Aldosterone: What is the overall purpose or function of this hormone? Is it secreted when blood pressure is high or low?

* why does K+ secretion INCREASE while Na+ reabsorption increases?

Antidiuretic hormone: What is the overall purpose or function of this hormone? Is it secreted when blood pressure is high or low?

1. **Write out and understand the renin angiotensin system (RAAS).**

Renin: released from juxtaglomerular cells into bloodstream in response to low blood pressure, sympathetic stimulation, and/or decreased Na+ concentration in the distal nephron.

1. Renin stimulates conversion of angiotensinogen (released from liver) into angiotensin I.
2. Angiotensin I is converted to angiotensin II in the lungs by angiotensin converting enzyme (ACE)
3. Angiotensin II leads to
   1. peripheral vasoconstriction
   2. release of aldosterone by the adrenal glands. Aldosterone stimulates Na+ reabsorption by the distal nephron (DCT)

***🡪 Main goal: INCREASE BLOOD PRESSURE!***

**THE TABLE:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Hormone** | **Secreted from** | **Site of action** | **Stimulus for secretion** | **Effects of the hormone** | **Urine output** |
| Renin | Juxta-glomerular cells | Plasma: it converts angiotensinogen to ang.1 | - ↓ in blood pressure  - Sympathetic activity | - Activates angiotensinogen, stimulates secretion  - Stimulates ADH release  - Stimulates aldosterone release  *Ultimately increase Na+ and water reabsorption at kidney* | ↓ |
| Angiotensinogen | Liver | Circulates in plasma in inactive form (angiotensinogen) | So far as we know this always circulates. | - Activated by renin, converted to angiotensin I, then to angiotensin II by angiotensin converting enzyme (ACE) in the lungs | ↓ |
| Natriuretic  Peptides | Heart  (right atrium) | Kidney, distal nephron or collecting ducts | - Stretch of right atrium (from ↑ in BP or blood vol.) | Blocks release of aldosterone  Naturesis, diuresis. | ↑ |
| Aldosterone | Adrenal  Cortex | Distal nephron, collecting ducts | Presence of Angiotensin II | Increases Na+ reabsorption. Results in water conservation. | ↓ |
| Antidiuretic  Hormone | Posterior  Pituitary | Collecting ducts | - ↓ in blood pressure  - ↑ in plasma osmolarity  (dehydration) | Increase water reabsorption in the kidney by increasing water permeability of collecting duct cells.  (↑ # of aquaporins) | ↓ |

***(4) Laboratory Math***

1. You learned that 10% of renal blood flow becomes filtrate. How much filtrate is formed in 1 minute?

*Renal blood flow = ~1.25 L/min, so filtrate is 1.25 L/min\* 10% = .125 L/min*

1. How much filtrate is formed in 1 hour?

*7.5 L/hour!*

1. How much filtrate is formed in 1 day?

*.125 L/min \* 60min/hour \* 24 hours/ day = 180 L/day*

1. How much filtrate is reabsorbed per day? Consider that roughly 2L of urine are formed per day.

*180 L/day filtrate – 2L urine per day = 178 L of filtrate is reabsorbed each day*

1. Speculate about the purpose of so much filtrate being formed. This seems crazy! What advantage might this give?

*(look up the term ‘clearance (pharmacology)’ on wikipedia!*

The kidneys can ‘CLEAR’ a substance form the blood very quickly if it is freely filterd. We can use glucose for an example. We know that 125 ml/min of filtrate is formed. If plasma glucose concentration is 100 mg/dl then 125 mg /min is filtered. In an hour we will have 7500 mg of glucose entering the nephrons. Another way to say that is 7500 mg of glucose is removed from plasma, per hour.

If this glucose was not reabsorbed then we can calculate how much plasma is ‘cleared’ of glucose. Clearance is THE VOLUME OF PLASMA THAT SUPPLIES THE AMOUNT EXRETED IN A GIVEN TIME. I know, this is hard to understand!

If plasma contains 125 mg/dl and we excrete 7500 mg in an hour then we can ‘clear’ 7500mg/125 mg/dl = 60 dl = 6L oer hour! The kidneys, by virtue of a high GFR, can clear substances really quickly!

Clearance rate INCREASEs if a substance is secreted, and DECREASES if a substance is reabsorbed.

1. Consider that plasma Na+ is 140 mM. If the GFR is 125 ml/min, how much Na+ is filtered per day?

*A=C\*V, M= mols/L*

*140 mmol/L Na+ \* 180 L filtrate per day = 25200 mmol or 25.2 mol of sodium*