Bio 230 Lecture Notes: THE URINARY SYSTEM

NOTE: You must follow along in your text book or the powerpoint supplied while reading through these lecture notes. A picture is worth a thousand words.

Urinary System:

2 kidneys, 2 Ureters, 1 bladder, 1 urethra

INTRODUCTION:

Major Functions of Kidneys:
When blood sugar (glucose) levels are low, the liver converts amino acids into glucose for energy. Amino acids come from the breakdown of protein in the GI tract. The conversion of amino acids to glucose results in the production of the nitrogenous waste product, ammonia (NH₃). Ammonia is extremely toxic to cells, so the liver converts NH₃ to the less toxic nitrogenous waste product, urea. Measured in our blood in the lab test BUN (Blood Urea Nitrogen). The URINARY SYSTEM removes urea and other metabolic waste products, toxins, excess water, and excess electrolytes (salts) from the bloodstream and eliminates them from the body in the form of urine. The process of eliminating metabolic wastes is called excretion.

The KIDNEYS are the excretory organs of the urinary system. As the kidneys perform their excretory function, they also regulate blood volume and the chemical makeup of the blood. They continuously maintain the proper balance between water and salts in the blood and they help to maintain the blood pH at 7.35-7.45, and help regulate blood pressure. Kidneys also release the hormone erythropoietin (EPO), which stimulates the bone marrow to produce more RBC’s (erythropoesis).

KIDNEYS: EXTERNAL ANATOMY (Follow along with your classroom models/worksheets)

Kidneys are kidney bean-shaped and reddish in color. (due to high vascularity-receive 25% of resting cardiac output). The adult kidney weighs 1/3 pound, is 4-5 inches long, 2-3 in. wide and 1 in. thick. The kidneys are located along the posterior abdominal wall, lateral to the vertebral column. They are retroperitoneal, extending from the level of the T12 vertebra to the level of the L3 vertebra. The kidneys receive some protection from the lower part of the rib cage and are surrounded by adipose for additional protection. The right kidney is slightly lower than left kidney. WHY?

The lateral surface of each kidney is convex. The medial surface is concave and has an indentation called the HILUM. The ureters, renal blood vessels, enter or exit the kidney at the hilum.

RENAL CAPSULE –outer protective membrane that is transparent and made of fibrous connective tissue. The renal capsule prevents infections in surrounding regions from spreading to the kidneys. It also protects the kidney from physical trauma.

KIDNEY: INTERNAL ANATOMY

A frontal section of the kidney reveals 3 distinct regions inside the renal capsule and they are the RENAL CORTEX, RENAL MEDULLA, & RENAL PELVIS.
1. RENAL CORTEX: the outer region just inside the renal capsule; light red in color and granular in appearance.
2. RENAL MEDULLA: deep to the cortex; a darker, reddish brown color. Arranged in cone-shaped regions called RENAL PYRAMIDS, which have a striated appearance. Each kidney has about 7-12
pyramids. Each pyramid tapers to an apex (papilla). The numerous tubules and ducts in the pyramids give it a striated appearance. (Be sure to see these striations on the models)

Extensions of the RENAL CORTEX between the renal pyramids are called RENAL COLUMNS. Together, the RENAL CORTEX & MEDULLA form a RENAL LOBE.

3. RENAL PELVIS: where the urine is collected and sent to the ureter. Each pyramid drains its formed urine into its own minor calyx. Minor calyces join to form major calyces with join to form the renal pelvis.

NEPHRONS:
Nephrons are contained within the renal lobes. Each kidney contain over 1 million microscopic NEPHRONS. Nephrons are the functional units of the kidneys because nephrons carry out the processes that form urine.

Parts of a Nephron:

<table>
<thead>
<tr>
<th>Vessels</th>
<th>Tubules</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. glomerulus</td>
<td>1. Glomerular (Bowman’s) capsule</td>
</tr>
<tr>
<td>2. afferents arteriole</td>
<td>2. Proximal convoluted tubule</td>
</tr>
<tr>
<td>3. efferent arteriole</td>
<td>3. Loop of Henle</td>
</tr>
<tr>
<td>4. peritubular capillary</td>
<td>4. Distal convoluted tubule</td>
</tr>
<tr>
<td>5. * vasa recta</td>
<td>5. Collecting duct</td>
</tr>
</tbody>
</table>
* (only in juxtamedullary nephron)

Each nephron consists of a RENAL CORPUSCLE (where urine is filtered).
The renal corpuscle consists of a cup-shaped structure called the GLOMERULAR (BOWMAN’S) CAPSULE and the capillary bed that it surrounds, called the GLOMERULUS. The renal corpuscle (Bowman’s capsule + glomerulus) are located in the RENAL CORTEX.

The pores of the GLOMERULUS (fenestrated capillary endothelium) and the filtration slits of the BOWMAN’S CAPSULE filter the blood as it moves through the glomerulus. Water and many solutes (glucose, salts, urea, drugs, vitamins, amino acids) can pass through the pores & filtration slits, but large molecules like plasma proteins and the formed elements of the blood (RBC’s & WBC’s) cannot. The water and solutes that filter out of the blood and are collected inside the glomerular capsule space are called the filtrate.

The glomerular (Bowman’s) capsule opens into the renal tubule.. The first section of the renal tubule is called the PROXIMAL CONVOLUTED TUBULE, which lies in the renal cortex. Notice that the cells that line the proximal convoluted tubule have microvilli on their apical surface (fig. 27.6a in McKinley). These cells reabsorb water and other needed substances from the filtrate and return them to the bloodstream (via the peritubular capillaries). Remember- microvilli (increase surface area)=increase the efficiency of reabsorption.

The proximal convoluted tubule straightens and becomes the DESCENDING LIMB OF THE LOOP OF HENLE, and then it makes a narrow U-turn called the LOOP OF HENLE. The loop turns back up toward the renal cortex as the ASCENDING LIMB OF THE LOOP OF HENLE.

Nephrons are classified into 2 types based on the location of the loop of Henle:
1. CORTICAL NEPHRONS: the loop of Henle is mostly in the cortex and penetrates a little into the medulla.
2. JUXTAMEDULLARY NEPHRONS: the loop of Henle penetrates deeply into the medulla, and the glomerular capsule is closer to the medulla. “juxta” means next too
In the renal cortex, the ascending limb of the loop of Henle becomes twisted again as the DISTAL CONVOLUTED TUBULE. The distal convoluted tubules of several nephrons empty into a COLLECTING DUCT. The collecting ducts absorb more water from the filtrate if needed. ADH (Anti Diuretic Hormone) acts on the collecting ducts to increase water reabsorption. ADH released from the pituitary gland when the body is “dry”, the urine becomes more concentrated, hence the name “anti” diuretic. Collecting ducts empty into a MINOR CALYX, minor calyces join to form MAJOR CALYXES, which delivers urine to the RENAL PELVIS, which transports the urine to the ureter of the kidney.

The filtrate is processed as it passes through these parts of the nephron. Needed substances, such as water, glucose and electrolytes (salts), are returned to the bloodstream. After the filtrate is processed by the nephron, it is called URINE. Urine contains urea and other metabolic wastes, toxins, excess salts, & excess water, as well as drugs and excess vitamins.

BLOOD SUPPLY OF THE KIDNEYS:
While the body is at rest, the large left and right RENAL ARTERIES deliver about about 1.2 liters of blood through the kidneys every minute (25 % of resting cardiac output). The renal arteries are branches of the ABDOMINAL AORTA. After each renal artery enters a kidney, it branches into numerous small arteries, which carry the blood to the renal cortex (where the Renal Corpuscles reside).

The blood flow through the kidney is: Renal artery ➔ segmental arteries ➔ interlobar arteries ➔ arcuate arteries ➔ interlobular arteries ➔ AFFERENT ARTERIOLES (one for each nephron). Each afferent arteriole, divides to form a capillary tuft called the GLOMERULUS. The glomerulus is surrounded by the glomerular capsule and is specialized for filtration of blood. The glomerular capillaries merge to form the EFFERENT ARTERIOLE, which leads away from the glomerular capsule.

The efferent arteriole's diameter is smaller than the afferent arteriole. This raises the blood pressure in the glomerulus, which aids in forcing water and solutes into the glomerular capsule.

Each efferent arteriole branches into a second capillary network called the PERITUBULAR CAPILLARIES. These capillaries cling closely to the PROXIMAL & DISTAL CONVOLUTED TUBULES of both cortical & juxtamedullary nephrons. The efferent arterioles of juxtamedullary nephrons also branch into the VASA RECTA, capillaries that surround the LOOP OF HENLE in the medulla. The peritubular capillaries and vasa recta are adapted for absorption. They absorb water and needed substances from the filtrate in the nephron, so that much of the water and solutes that the body requires are returned to the bloodstream rather than flushed out in the urine. Toxins and excess water and solutes remain in the filtrate and are eliminated as urine. The peritubular capillaries and vasa recta merge into venules ➔ interlobular vein ➔ arcuate veins ➔ interlobar veins ➔ that join and which empty into the RENAL VEIN. (note no segmental veins as counterpart to arterial side)

The RENAL VEIN of each kidney leaves the kidney through the hilum. The renal vein of each kidney returns freshly cleansed blood to the INFERIOR VENA CAVA.

URETERS:
The URETERS are slender tubes about 10-12 in long that carry urine from the kidneys to the urinary bladder. Each ureter runs posterior to the parietal peritoneum (retroperitoneal) from the renal hilum to the level of the urinary bladder. At the urinary bladder, each ureter makes a medial turn toward the bladder and enters the posterior bladder wall at an oblique angle, which prevents backflow of urine from the bladder into the ureters.

The inner lining of the ureter wall is MUCOSA that consists of transitional epithelium, that stretches as urine passes through. Mucus secreted by the mucosa protects the epithelial cells from coming into contact with the urine, which contains toxins and is slightly acidic. Beneath the mucosa is the MUSCULARIS, which is composed of smooth muscle arranged in circular and longitudinal layers. The muscularis creates
peristaltic contractions, similar to those in the GI tract.
When the renal pelvis fills with urine, smooth muscle in the renal pelvis wall contracts rhythmically, sending urine into the ureter. Peristalsis propels the urine through the ureter to the urinary bladder.

URINARY BLADDER:
The URINARY BLADDER is a hollow muscular organ located in the pelvic cavity posterior to the pubic symphysis. Like the kidneys and ureters, the urinary bladder is retroperitoneal. In males the urinary bladder lies anterior to the rectum. In females the bladder is superior to the vagina and inferior to the uterus. Looking at your workshhet can you now understand why pregnant women have such bladder holding problems as the uterus get larger and larger! The function of the urinary bladder is the temporary storage of urine. Structures to find include the openings of the 2 ureters into the bladder and the urethra opening, which form the TRIGONE “triangle”.
The inner wall of the urinary bladder consists of a MUCOSA made of transitional epithelium which is able to stretch a great deal. Mucus produced by the bladder mucosa helps protect the wall from urine. Beneath the mucosa is smooth muscle, arranged in circular and longitudinal layers. The smooth muscle in the wall allows the bladder to stretch a great deal.
When empty, the bladder is 2-3 in long. Its walls are thick and its mucosa is thrown into folds called RUGAE (remember this term from the stomach?). When urine accumulates in the bladder, it expands and becomes pear-shaped as it rises upward in the pelvic cavity. The transitional epithelium and smooth muscle stretches and thins. This increases the internal volume of the bladder by decreasing the thickness of its wall. A moderately full bladder is about 5 in long and holds about 500 ml of urine. The average capacity of the bladder is 700-800 ml. When the volume of urine in the bladder exceeds 200-400 ml, stretch receptors in the bladder transmit nerve impulses to the brain, initiating the conscious desire to urinate. The constricted NECK of the bladder is where the Urethra leaves the bladder. Here is where the INTERNAL URETHRAL SPHINCTER is located. Smooth muscle, involuntary control.

URETHRA:
The URETHRA is a muscular tube that drains urine from the urinary bladder and conveys it out of the body.
The INTERNAL URETHRAL SPHINCTER is an involuntary smooth muscle sphincter at the base of urinary bladder, Just distal to the bladder neck.
The EXTERNAL URETHRAL SPHINCTER is a voluntary skeletal muscle sphincter in the UROGENITAL DIAPHRAGM. You control this one. The muscle toddlers learn to control when “toilet training”.

THE FEMALE URETHRA:
The urethra in females is short. It is only about about 1.5 inches lengthwise. The lining epithelium of the female urethra is psuedostratified columnar epithelium at its most promimal and then becomes stratified squamous epithelium.

MALE URETHRA:
The urethra in the male is longer than the urethra of females. The male urethra is 7 to 8 inches lengthwise (variable). The male urethra functions as a conduit for urine and semen. The male urethra is divided into three sections: prostatic urethra, membranous urethra, and spongy (penile) urethra. Make sure you can find these 3 regions.

Histology of the Prostatic Urethra
The first portion of the male urethra is the prostatic urethra. This portion of the urethra goes through the prostate gland. The prostatic urethra is lined by transitional epithelium.
Histology of the Membranous Urethra
The second part of the male urethra is the membranous urethra. This is a short segment where it passes through the urogenital diaphragm (external sphincter). The lining epithelium of the membranous urethra is pseudostratified columnar epithelium.

Histology of the Spongy Urethra
The third part of the urethra is the spongy urethra. The spongy urethra is also called the penile urethra. This is the longest section of the male urethra. It travels through the corpus spongiosum of the penis. The lining epithelium of the spongy urethra is pseudostratified columnar epithelium which then transitions to stratified squamous epithelium distally.

Incontinence “gatta go”. Pregnant women…don’t forget your kegels!