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Human Anatomy and Physiology
Chapter 13 : Urinary System

Topics	Page No
Urinary System	3
Kidneys	3
Anatomy and Physiology Kidney	3
Physiology of Urine Formation	8
Micturition	9
Clearance Test	9

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Chapter 13

Urinary System

- Urinary system of the body is formed by the organs responsible for converting the excess fluid and other substances into urine, its filtration, and its excretion from the body.
- These organs include kidneys, ureters, urinary bladder, and urethra. Urine is formed by the kidneys, then sent to the urinary bladder for storage, and finally excreted through urethra.
- Urine excretes excess of minerals, vitamins, and blood cells from the body.
- Urinary system along with the other systems of the body maintains homeostasis. Kidneys play a major role in homeostasis as they maintain the acid base and water salt balance in the blood.

Parts of Urinary System

The urinary tract is made up of the following organs:

1) A pair of kidneys (forming urine).
2) A pair of ureters (transporting urine),
3) A urinary bladder (storing urine), and
4) A urethra (carrying urine outside the body).)

Kidneys

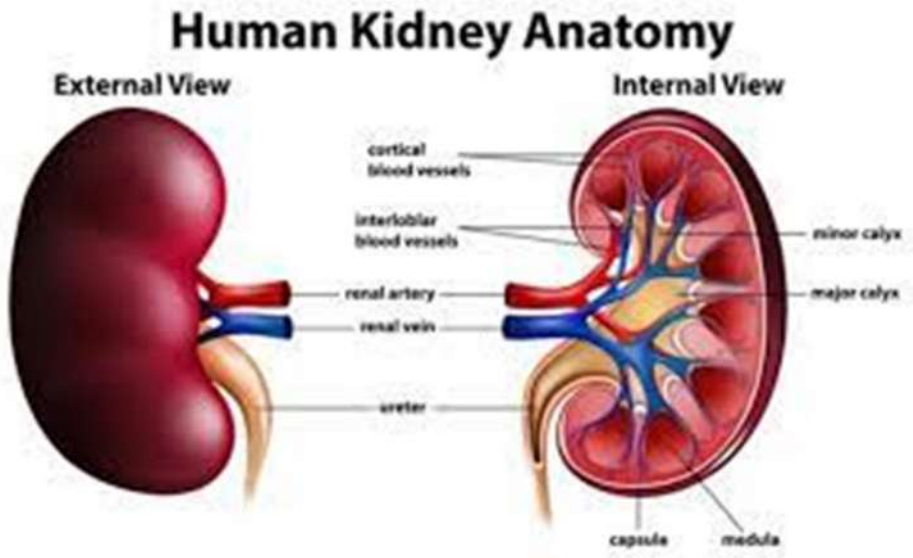
→ Kidneys are present in pair in vertebrates as well as in some invertebrates.
→ They are the major organs of urinary system.
→ They produce urine through which waste materials such as urea and ammonia are excreted.
→ They also reabsorb glucose and amino acids.

Along with this, kidneys also perform secretory function, e.g.. calcitriol, erythropoietin, and renin are some of the hormones produced by kidneys.

Kidneys also perform some other homeostatic functions, like:

1) Regulate electrolyte balance,
2) Maintain acid-base balance, and
3) Control the blood pressure.

Anatomy and Physiology



- Kidneys are bean-shaped and positioned in a retroperitoneal position (ie., between the dorsal body wall and the parietal peritoneum) in the superior lumbar region.
- The right kidney is present slightly lower than the left. Mass of an adult kidney is about 150gm and is 12cm long, 6cm wide, and 3cm thick.)
- The kidneys have a convex lateral surface and a concave medial surface. They also have a vertical cleft (the renal hilum) leading into an internal space within the kidney (the renal sinus).
- Hilum forms the area where the ureters, renal blood vessels, lymphatics, and nerves join the kidney.

Functions

I. Regulation of Blood Ionic Composition: They regulate the concentration of some ions (Na', K, Cart C and HPO, ') in blood.)

II. Regulation of Blood pH: They regulate blood pH (Potential of Hydrogen) by excreting Ht lons into the urine and conserving HCO, ions (an important buffer of Ht ions in the blood

III. Regulation of Blood Volume: They regulate blood volume by conserving water or eliminating the excess in urine. Blood volume in turn regulates the blood pressure, since an increase in blood volume increases blood pressure and vice versu.

IV. Regulation of Blood Pressure: They regulate blood pressure by secreting remin enzyme which activates the renin-angiotensin-aldosterone pathway. Renin in increased amount increases the blood pressure.)

V. Maintenance of Blood Osmolarity: They maintain a constant blood osmolarity [value of which is close to 300 milliosmoles per litre (mOsm/litre)] by regulating loss of water and solutes in the urine.)

VI. Production of Hormones: They produce calcitriol (the active form of vitamin D) which regulates calcium homeostasis; and erythropoietin which stimulates RBC production.

VII. Regulation of Blood Glucose Level: They utilise glutamine amino acid in gluconeogenesis (synthesis of new glucose molecules), and then release the resultant glucose into the blood for maintaining the glucose level.

VIII. Excretion of Wastes and Foreign Substances: They form urine to excrete waste materials (ammonia and urea resulting from deamination of amino acids, bilirubin from catabolism of haemoglobin, creatinine from breakdown of creatine phosphate in muscle fibres, and uric acid from catabolism of nucleic acids), Foreign substances from the diet such as drugs and environmental toxins are also excreted.

Nephrons

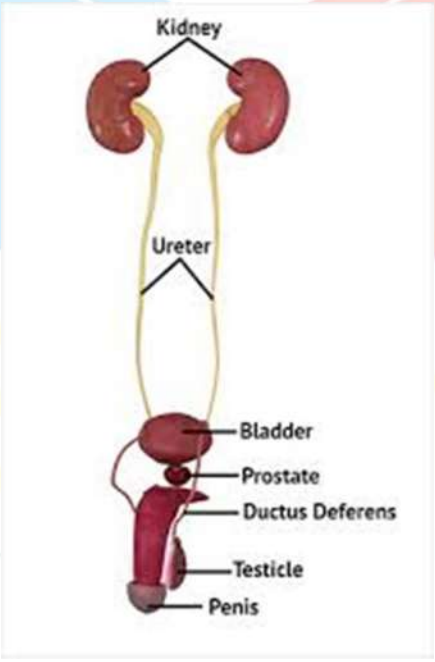
→ Nephron is the basic structural and functional unit of the kidney. It filters the blood out [of waste materials, reabsorb the required ones, and excrete the remaining with urine; thus regulates the concentration of water and soluble substances like sodium salts in the blood

Ureters

→ Ureters are paired tubes through which the urine flows from the kidneys to the urinary bladder. Both the tubes begin from the sinus of the corresponding kidney as calyces (short cup-shaped tubes) surrounding the renal papillae. More than one papilla are enclosed within a single calyx; thus the calyces are fewer in number (ranging 7 to 13) than the pyramids (ranging between 8-18).

→ The calyces combine with each other to form 2-3 short tubes, which further combine to form renal pelvis (a funnel-shaped dilatation with wide above and narrow below, situated partially inside and partially outside the renal sinus).

Anatomy and Physiology



I. Ureters are 25-30cm Tong, thick-walled, narrow cylindrical tubes. They begin near the lower end of the kidney with the tapering extremity of the renal pelvis. They run downward and medially in front of the Psoas major, enter the pelvic cavity, and terminate in the fundas of the urinary bladder.

II. Ureter is enclosed within the following three coats

Tunica (Fibrous Coat) : One end of this coat is continuous with the fibrous tunic of the kidney on the sinus floor, and the other end is somewhere within the fibrous bladder.

Tunica Muscularis (Muscalar Coat):) This coat in the renal pelvis is further made up of two layers:

I. Longitudinal Fibre: This layer lies on the sides of the papillae at the extremities of the calyces.

II. Circular Fibre: This layer surrounds the: medullary substance.

Tunica Mucosa (Mucous Cont):) This smooth coat has a few longitudinal folds which erode on distension. It joins the mucous membrane of the bladder, while it is prolonged over the papillae of the kidney.

Functions

Ureters perform the following functions

1) They transport urine from the renal pelvis of the kidney to the urinary bladder.

2)Since they pass beneath the urinary bladder, duringg urination when pressure in the bladder is high the ureters are compressed and back-flow of urine is prevented. Otherwise, cystitis (inflammation of the ureter/urinary bladder) may develop which may lead to a kidney infection.

Urinary Bladder

→ Urinary bladder is a hollow [muscular, and distensible or elastic) organ which rests on the pelvic floor.

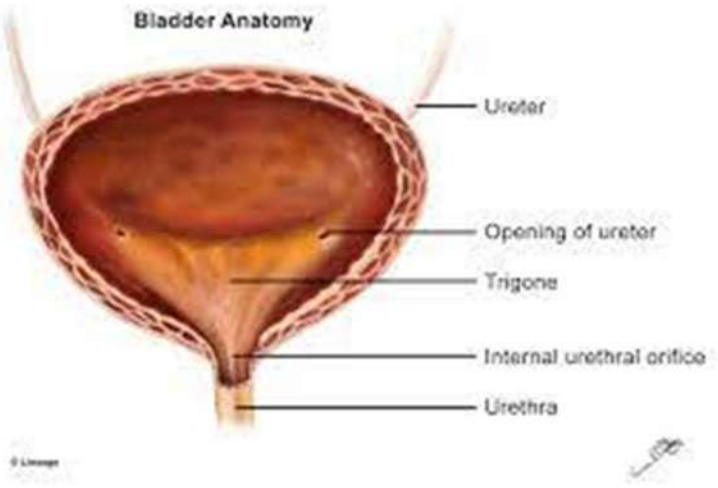
→ It receives urine from the kidneys via the ureters, stores it within, and expels it during urination via the urethra.

→ It is a reservoir where urine is stored temporarily.

→ The bladder is somewhat spherical in shape, although its shape and size vary from individual to individual and also depends on the urine volume it stores.

→ An empty bladder is about the size and shape of a pear The normal capacity of the bladder is 400 – 600 ml

Anatomy and Physiology



➲ Urinary bladder is situated in the pelvic cavity posteriorly to the symphysis pubis, and inferiorly to the parietal peritoneum.

It is made up of three layers

1)Mucous Membrane: It is the inner lining of the bladder consisting of transitional epithelium continuous with that of the ureters.

2) Submucosa : It is the second layer, consisting of connective tissue with elastic fibres and supporting the mucous membrane.

3) Muscularis: It is the outer layer consisting of smooth muscles having fibres interwoven in all directions, collectively termed detrusor muscle.

Functions

Urinary bladder performs the following functions:

1) It is a reservoir for urine,

2) It expels urine via urethra.

A urinary bladder filled with urine becomes distended.

Urine stimulates the stretch receptors on the bladder wall, which in turn trigger a reflex contraction of the bladder wall muscles and relax the internal sphincter (a valve which remains closed so that the urine remains in the bladder till urination), Soon the external sphincter relaxes and the bladder expels the urine. A parasympathetic nerve fibre transmits a signal that causes bladder contractions and internal sphincter relaxations.

Urethra

- A Urethra is in tube-like structure which transports urine from the urinary bladder to the exterior of the body.
- It forms the "exit tube" of the body for liquid wastes.
- It is closed by the external urethral sphincter (a muscular structure) which keeps the urine in the bladder till urination.
- Mucous membranes form the inner lining of the urethra, and muscular layer forms the outer layer.
- The smooth muscle fibre directs longitudinally The urethral walls have highly specialised urethra glands which constantly secrete mucous coating the urethral canal.

Anatomy and Physiology

- Urethra is made up of two separate urethral sphincter muscles.
- The internal urethral sphincter muscle consists of involuntary smooth muscles, while the external sphincter muscle consists of lower voluntary muscles.
- Detrusor muscle makes up the internal sphincter

The characteristic features of female and male urethra are:

a. Female Urethra: It is 4cm long and opens to the exterior via urethral orifice, located in the vestibule in the labia minora between the clitoris and the Vaginal orifice Female urethra transports urine from the bladder to outside at the time of urination.

b. Male Urethra: It is 20cm long, S-shaped, follows the line of the penis. It transports urine during (urination) and semen (during ejaculation) to outside Male urethra consists of the following three regions

Functions

Urethra performs the following functions:

1) It is the passageway through which urine is expelled out of the body.

2) In males, it is also the passageway through which semen is ejaculated.

Physiology of Urine Formation

→ The cells of the body produce nitrogenous wastes which are transported via blood to the kidneys.

→ Here they are converted into urine by the following three processes:

- Ultrafiltration or glomerular filtration,
- Tubular reabsorption, and
- Tubular secretion (augmentation).

Ultrafiltration/Glomerular Filtration

➢ Ultrafiltration (or glomerular filtration) is a passive process involving hydrostatic pressure to force fluids and solutes across a membrane.

➢ Glomerulus filters wastes more efficiently because its filtration membrane has larger surface area and is thousand times more permeable to water and solutes in comparison to the other capillary beds.

➢ Water, glucose, amino acids, and nitrogenous wastes are molecules having <3nm diameter; they can easily move into the glomerular capsule from the blood, thus have similar concentrations in blood as well as the glomerular filtrate.

➢ Molecules of 3-5nm diameter enter the glomerular capsule with much difficulty, while those of >5am diameters are prevented from entering the tubule

Tubular Reabsorption

➢ Tubular reabsorption, a selective transepithelial process initiates when the filtrate enters the proximal tubules. The reabsorbed substances enter the blood via:

- Transcellular route
- Paracellular route

Tubular secretion (augmentation).

➢ The plasma is cleared from unwanted substances by tubular secretion (reverse of reabsorption). The H*, K*, NH, creatinine, and certain organic acids either are synthesised in the tubule cells and secreted, or they reach the filtrate by passing through the tubule cells from the peritubular capillaries.

Renin Angiotensin System (RAS)

→ The Renin-Angiotensin Aldosterone System (RAAS) is essentially required for regulating blood volume and systemic vascular resistance.

→ Renin is released when stimulated by:

- Increased sympathetic nerve activation (acting through Pr-adrenoceptors),
- Decreased renal artery hypotension (caused by systemic hypotension or renal artery stenosis), and
- Decreased sodium delivery to the distal tubules of the kidney.

Micturition

- When 300-400ml of urine has been collected in the urinary bladder, the afferent autonomic nerve fibres in the bladder wall which are sensitive to stretch are stimulated.
- In infants, fullness of bladder initiates a spinal reflex action to cause micturition
- When the autonomic efferent fibres send impulses to the bladder, the detrusor muscles contract and the internal urethral sphincter relaxes, thus causing micturition.
- In adults, nervous system is fully developed, so micturition reflex is stimulated and sensory impulses are passed to the brain to make the individual aware of the desire to urinate.
- In adults, contraction of the detrusor muscles, reflex relaxation of the internal sphincter, and voluntary relaxation of the external sphincter causes micturition
- This mechanism can be supported by lowering the diaphragm and contracting the abdominal muscles (Valsalva's manoeuvre) which in turn increases the pelvic cavity pressure.
- When the bladder is over distended it becomes extremely painful, and in this stage there is an involuntary tendency to relax the external sphincter and release a small amount of urine; although there should be no mechanical hindrance.

Clearance Test

→ The volume of plasma that is cleared of that substance in unit time is known as clearance of substance.

→ GFR is precisely measured by inulin clearance, as it is neither secreted nor absorbed by the renal tubules.

→ Clearnace test are not performed on regular basis in patients.

→ Using serum creatinine value, estimated GFR (eGFR) is also calculated in clinical setting.

→ Healthy kidneys remove wastes and excess fluid from the blood.

→ Different blood and urine tests examine the proper functioning of the kidneys and their ability to remove body wastes.

→ Urine tests are also performed to detect the signs of kidney damage, e.g., whether they are leaking abnormal amounts of protein or not.

→ Following clearance test are performed to examine the urinary system:

- Blood Tests
- Imaging Tests