جامعة الفرات الاوسط التقنية /المعهد التقني سماوة

قسم تقنيات صحة مجتمع

المحاضرة13

اسم المادة / وظائف اعضاء 1.

المرحلة الدراسية / الاولى

العام الدراسي / 2022 - 2023

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1-14 The formation of urine

Filtration ,reaborption ,and secretion.

1- Filtration

Urine formation begins with the process of filtration, which goes on continually in the renal corpuscles.As blood courses through the glomeruli, much of its fluid, containing both useful chemicals and dissolved waste materials, soaks out of the blood through the membranes (by osmosis and diffusion) where it is filtered and then flows into the Bowman's capsule. This process is called glomerular filtration. The water, waste products, salt, glucose, and other chemicals that have been filtered out of the blood are known collectively as glomerular filtrate. The glomerular filtrate consists primarily of water, excess salts (primarily Na^+ and K^+), glucose, and a waste product of the body called urea. Urea is formed in the body to eliminate the very toxic ammonia products that are formed in the liver from amino acids. Since humans cannot excrete ammonia, it is converted to the less dangerous urea and then filtered out of the blood. Urea is the most abundant of the waste products that must be excreted by the kidneys. The total rate of glomerular filtration (glomerular filtration rate or GFR) for the whole body (i.e., for all of the nephrons in both kidneys) is normally about 125 ml per minute. That is, about 125 ml of water and dissolved substances are filtered out of the blood per minute.

2- Reabsorption

Reabsorption, by definition, is the movement of substances out of the renal tubules back into the blood capillaries located around the tubules (called the peritubular copillaries). Substances reabsorbed are water, glucose and other nutrients, and sodium (Na^+) and other ions. Reabsorption begins in the proximal convoluted tubules and continues in the loop of Henle, distal convoluted tubules, and collecting tubules (Figure 3). Let's discuss for a moment the three main substances that are reabsorbed back into the bloodstream.

Large amounts of water - more than 178 liters per day - are reabsorbed back into the bloodstream from the proximal tubules because the physical forces acting on the water in these tubules actually push most of the water back into the blood capillaries. In other words, about 99% of the 180 liters of water that leave the blood each day by glomerular filtration returns to the blood from the proximal tubule through the process of passive reabsorption.

The nutrient glucose (blood sugar) is entirely reabsorbed back into the blood from the proximal tubules. In fact, it is actively transported out of the tubules and into the peritubular capillary blood. None of this valuable nutrient is wasted by being lost in the urine. However, even when the kidneys are operating at peak efficiency, the nephrons can reabsorb only so much sugar and water. Their limitations are

dramatically illustrated in cases of diabetes mellitus, a disease which causes the amount of sugar in the blood to rise far above normal. As already mentioned, in ordinary cases all the glucose that seeps out through the glomeruli into the tubules is reabsorbed into the blood. But if too much is present, the tubules reach the limit of their ability to pass the sugar back into the bloodstream, and the tubules retain some of it. It is then carried along in the urine, often providing a doctor with her first clue that a patient has diabetes mellitus. The value of urine as a diagnostic aid has been known to the world of medicine since as far back as the time of Hippocrates. Since then, examination of the urine has become a regular procedure for physicians as well as scientists.

Sodium ions (Na^+) and other ions are only partially reabsorbed from the renal tubules back into the blood. For the most part, however, sodium ions are actively transported back into blood from the tubular fluid. The amount of sodium reabsorbed varies from time to time; it depends largely on how much salt we take in from the foods that we eat. (As stated earlier, sodium is a major component of table salt, known chemically as sodium chloride.) As a person increases the amount of salt taken into the body, that person's kidneys decrease the amount of sodium reabsorption back into the blood. That is, more sodium is retained in the tubules. Therefore, the amount of salt excreted in the urine increases. The process works the other way as well. The less the salt intake, the greater the amount of sodium reabsorbed back into the blood, and the amount of salt excreted in the urine decreases.

3- secreation

Now, let's describe the third important process in the formation of urine. Secretion is the process by which substances move into the distal and collecting tubules from blood in the capillaries around these tubules. In this respect, secretion is reabsorption in reverse. Whereas reabsorption moves substances out of the tubules and into the blood, secretion moves substances out of the blood and into the tubules where they mix with the water and other wastes and are converted into urine. These substances are secreted through either an active transport mechanism or as a result of diffusion across the membrane. Substances secreted are hydrogen ions (H+), potassium ions (K+), ammonia (NH3), and certain drugs. Kidney tubule secretion plays a crucial role in maintaining the body's acid-base balance, another example of an important body function that the kidney participates in.

Summary

In summary, three processes occurring in successive portions of the nephron accomplish the function of urine formation:

1. **Filtration of water and dissolved substances out of the blood in the glomeruli and into Bowman's capsule;**
2. **Reabsorption of water and dissolved substances out of the kidney tubules back into the blood (note that this process prevents substances needed by the body from being lost in the urine);**

3. **Secretion of hydrogen ions (H^+), potassium ions (K^+), ammonia (NH_3), and certain drugs out of the blood and into the kidney tubules, where they are eventually eliminated in the urine.**

2-14 the urine

is the fluid excreted by the kidneys. It consists of water, carrying in solution the body's waste products such as urea, uric acid, creatinine, organic acids, and also other solutes such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, the body fluid concentrations of which are regulated by the kidneys.

After being produced by the kidneys, urine passes along the *ureters* to be stored in the bladder, until it is allowed to flow out of the body through the urethra, in the process of *micturition* (urination). The smooth muscle of the bladder forms an internal sphincter at its junction with the urethra, and further along the urethra is the voluntary-control external sphincter. The bladder begins to contract (micturition reflex), and produces the desire to urinate, when its volume exceeds about 200 ml. However, if we do not relax the external sphincter, the contractions subside, but return with increasing force and frequency as the bladder continues to fill. When the bladder volume is about 500 ml the micturition reflex may force open the internal sphincter and lead to a reflex relaxation of the external sphincter, so that urination occurs involuntarily.

Voluntary urination involves relaxation of the external sphincter and tensing of the abdominal muscles to increase abdominal pressure and compress the bladder, to initiate bladder contraction and relaxation of the internal sphincter.

Most people excrete about 1.5 litres of urine per day, but the volume can range (in healthy adults) from 400 ml up to about 25 litres, depending on fluid intake. In renal failure, there may be no urine production, and in the rare condition of untreated *diabetes insipidus*, the urine volume is consistently 25 litres/day. Urine is termed 'dilute' if its solute concentration (osmolality) is lower than that of the blood plasma, and 'concentrated' if its solute concentration is greater than that of the plasma.

Humans who are maximally conserving water — when their kidneys are reabsorbing as much as possible — can produce urine with a solute concentration (osmolality) about five times that of blood plasma. Many other animals can conserve water much more effectively. For example, cats, dogs, and rats can produce urine of ten times the plasma osmolality, and gerbils twenty times!

When voided, urine is normally sterile and clear, although it has a yellow colour due to the presence of pigments. However, small amounts of particulate matter such as epithelial cells and lipids may be present; these are 'casts'. Protein is not normally filtered from the blood plasma by the kidneys, so protein in the urine — *proteinuria* — is generally indicative of damage to the glomeruli, at the blind inner ends of the kidney tubules, where filtration occurs. The urine may also appear to contain blood (*haematuria*). This may be due to haemolysis in the bloodstream (breakdown of red cells) so that some haemoglobin is released from them and excreted, or it may be due to the presence of whole red cells, as a result of bleeding in the kidneys or urinary tract.