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URINE FORMATION AND CONCENTRATION

Urine is a waste byproduct formed from excess water and metabolic waste molecules during the process of renal system filtration. The primary function of the renal system is to regulate blood volume and plasma osmolarity, and waste removal via urine is essentially a convenient way that the body performs many functions using one process.

There are three stages involved in the process of urine formation. They are-

1. Glomerular filtration or ultra-filtration

2. Selective reabsorption

3. Tubular secretion

Glomerular filtration

This takes place through the semipermeable walls of the glomerular capillaries and Bowman's capsule.

The afferent arterioles supplying blood to glomerular capsule carries useful as well as harmful substances. The useful substances are glucose, aminoacids, vitamins, hormones, electrolytes, ions etc and the harmful substances are metabolic wastes such as urea, uric acids, creatinine, ions, etc.

The diameter of efferent arterioles is narrower than afferent arterioles. Due to this difference in diameter of arteries, blood leaving the glomerulus creates the pressure known as hydrostatic pressure.

The glomerular hydrostatic pressure forces the blood to leaves the glomerulus resulting in filtration of blood. A capillary hydrostatic pressure of about 7.3 kPa (55 mmHg) builds

up in the glomerulus. However this pressure is opposed by the osmotic pressure of the blood, provided mainly by plasma proteins, about 4 kPa (30 mmHg), and by filtrate hydrostatic pressure of about 2 kPa (15 mmHg in the glomerular capsule.

The net filtration pressure is,

Therefore: 55-(30 +15) = 10mmHg.

By the net filtration pressure of 10mmHg, blood is filtered in the glomerular capsule.

Water and other small molecules readily pass through the filtration slits but Blood cells, plasma proteins and other large molecules are too large to filter through and therefore remain in the capillaries.

The filtrate containing large amount of water, glucose, aminoacids, uric acid, urea, electrolytes etc in the glomerular capsule is known as nephric filtrate of glomerular filtrate.

The volume of filtrate formed by both kidneys each minute is called the glomerular filtration rate (GFR). In a healthy adult the GFR is about 125 mL/min, i.e. 180 litres of filtrate are formed each day by the two kidneys

Selective reabsorption

As the filtrate passes to the renal tubules, useful substances including some water, electrolytes and organic nutrients such as glucose, aminoacids, vitamins hormones etc are selectively reabsorbed from the filtrate back into the blood in the proximal convoluted tubule.

Reabsorption of some substance is passive, while some substances are actively transported. Major portion of water is reabsorbed by Osmosis.

Only 60–70% of filtrate reaches the Henle loop. Much of this, especially water, sodium and chloride, is reabsorbed in the loop, so that only 15–20% of the original filtrate reaches the distal convoluted tubule, More electrolytes are reabsorbed here, especially sodium, so the filtrate entering the collecting ducts is actually quite dilute.

The main function of the collecting ducts is to reabsorb as much water as the body needs.

Nutrients such as glucose, amino acids, and vitamins are reabsorbed by active transport. Positive charged ions ions are also reabsorbed by active transport while negative

charged ions are reabsorbed most often by passive transport. Water is reabsorbed by osmosis, and small proteins are reabsorbed by pinocytosis.

Tubular secretion

Tubular secretion takes place from the blood in the peritubular capillaries to the filtrate in the renal tubules and can ensure that wastes such as creatinine or excess H+ or excess K+ ions are actively secreted into the filtrate to be excreted.

Excess K+ ion is secreted in the tubules and in exchange Na+ ion is reabsorbed otherwise it causes a clinical condition called Hyperkalemia.

Tubular secretion of hydrogen ions (H+) is very important in maintaining normal blood pH.

Substances such as , e.g. drugs including penicillin and aspirin, may not be entirely filtered out of the blood because of the short time it remains in the glomerulus. Such substances are cleared by secretion from the peritubular capillaries into the filtrate within the convoluted tubules.

The tubular filtrate is finally known as urine. Human urine is usually hypertonic.

Composition of human urine

- Water – 96%
- Urea – 2%
- Uric acids, creatinine, pigments- 0.3%
- Inorganic salts – 2%
- Bad smell is due to Urinoid
- Pale yellow color due to urochrome or urobillin (which is a breakdown product of haemoglobin)

Micturation:

The process of time to time collection and removal of urine from urinary bladder is known as micturition. Collection of more than 300ml of urine in urinary bladder creates

pressure on the wall. The pressure stimulates the desire for urination.

The concentration of urine

As already indicated, the loop of Henle is critical to the ability of the kidney to concentrate urine. The high concentration of salt in the medullary fluid is believed to be achieved in the loop by a process known as countercurrent exchange multiplication. The principle of this process is analogous to the physical principle applied in the conduction of hot exhaust gases past cold incoming gas so as to warm it and conserve heat. That exchange is a passive one, but in the kidney the countercurrent multiplier system uses energy to "pump" sodium and chloride out of the ascending limb of the loop into the medullary fluid. From there it enters (by diffusion) the filtrate (isotonic with plasma) that is entering the descending limb from the proximal tubule, thus raising its concentration a little above that of plasma. As this luminal fluid in turn reaches the ascending limb, and subsequently the distal tubule, it in turn provides more sodium to be pumped out into the surrounding fluid or blood, if necessary, and transported (by diffusion) back into the descending limb; this concentrating process continues until the osmotic pressure of the fluid is sufficient to balance the resorptive power of the collecting ducts in the medulla, through which all of the final urine must pass. This resorptive capacity in the ducts is regulated by antidiuretic hormone (ADH), which is secreted by the hypothalamus and stored in the posterior pituitary gland at the base of the brain. In the presence of ADH, the medullary collecting ducts become freely permeable to solute and water. As a consequence, the fluid entering the ducts (en route to the renal pelvis and subsequent elimination) acquires the concentration of the interstitial fluid of the medulla; i.e., the urine becomes concentrated. On the other hand, in the absence of ADH, the collecting ducts are impermeable to solute and water, and, thus, the fluid in the lumen, from which some solute has been removed, remains less concentrated than plasma; i.e., the urine is dilute.