UGS

UROGENITAL SYSTEM ®

slides Physiology

Number 1

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Correction

Renal Physiology

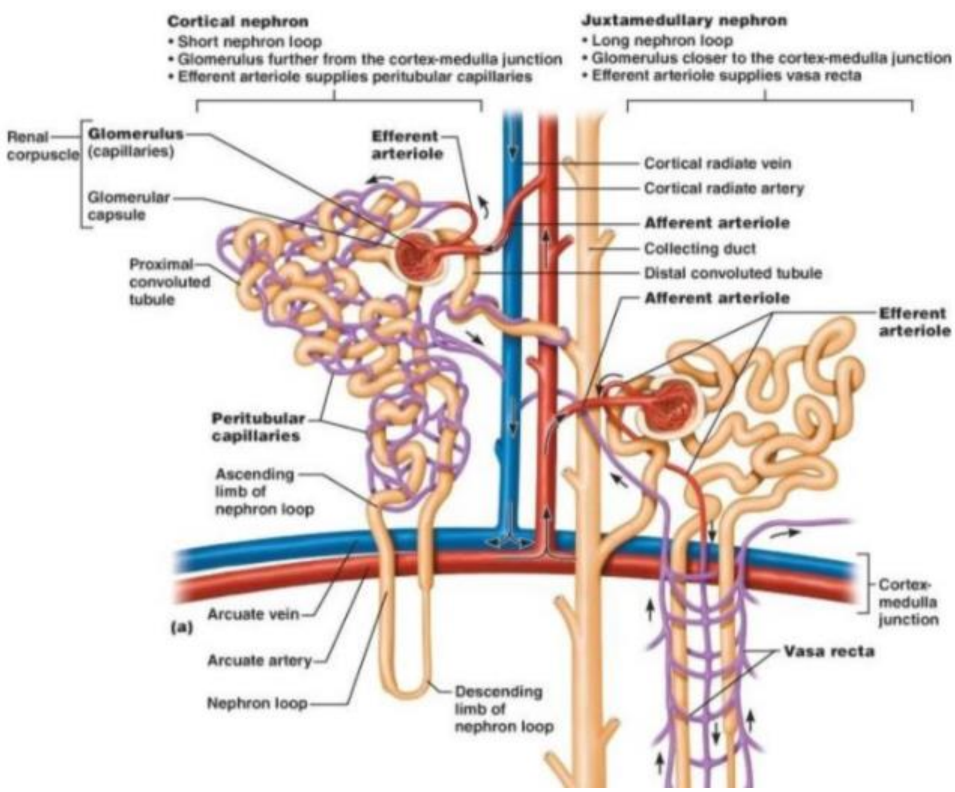
Kidneys are essential for life and we cannot survive without the normal functions of the kidney, and an abnormality in its functions may be enough to kill us. Its functions include:

- Homeostasis of the electrolytes
  one of them is potassium, so kidney failure causes hyperkalemia which causes severe cardiac arrhythmias
- Remove waste products and foreign chemicals
  like urea, creatinine and uric acid
- Acid-base balance (Hydrogen homeostasis)
  Kidney failure causes acidosis (accumulation of Hydrogen)
- Regulate fluids volume of the body, and thus, blood pressure
  Kidney failure causes retention of fluid and thus high blood pressure which causes edema (pulmonary edema is fatal)
- Secrete hormones such as erythropoietin, which is important for erythropoiesis
  Kidney failure causes anemia
- Convert 25-hydroxycholecalciferol into 1,25-dihydroxycholecalciferol (calcitriol), the most active form of vitamin D
  Kidney failure causes Calcium disturbances
- Gluconeogenesis (conversion of non-sugar sources, particularly amino acids, into glucose)

Blood supply to the kidneys

• The renal artery (the fifth branch of the aorta) enters the kidney through its hilum and divides many times to form segmental arteries → interlobar arteries → arcuate arteries → interlobular arteries (cortical radiate arteries).
• Interlobular arteries divide again into many afferent arterioles.
• Each afferent arteriole enters a glomerulus and divides to form the glomerular capillaries.

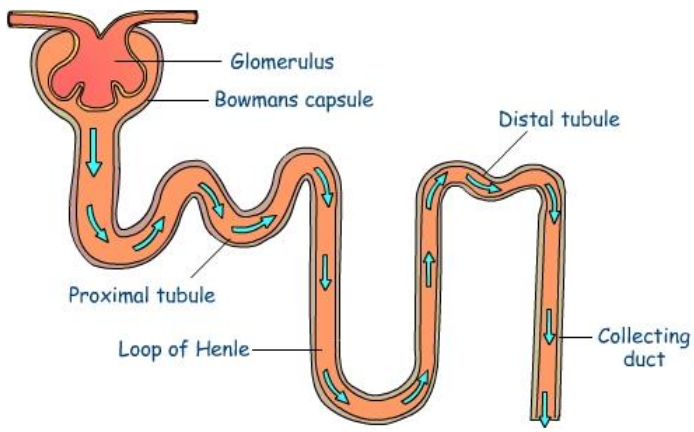
• The capillaries converge again to form efferent arterioles
• Efferent arterioles leave the glomerulus and divide, once again, to form peritubular capillaries.
• Peritubular capillaries rejoin to form interlobular veins → arcuate veins → interlobar veins.
• Interlobar veins join to form the renal vein which leaves the kidney through its hilum.
** Note that the glomerular capillaries did not form venules, but instead efferent arterioles, which divide again (instead of converging) to form other capillaries. This is known as the portal circulation.



Nephrons

Each kidney contains one million nephrons which consists of a renal corpuscle and a renal tubule; and a renal corpuscle consists of Bowman's capsule surrounding a network of glomerular capillaries (glomerulus) which receives blood through the afferent arteriole and then the blood leaves through efferent arteriole
The renal tubule consist of a proximal tubule, loop of Henle, distal tubule and a collecting duct. The tubule is 6cm long.

We divide it into two parts; one is for ultra-filtration and one for modification (secretion and reabsorption) and then the urine is excreted.
So Excretion= Filtration + Secretion – reabsorption
** an abnormality in the kidneys is either in the glomerulus responsible for filtration (glomerulonephritis) or in the tubules responsible for modification (tubulonephritis)



The blood is pumped from the left ventricle with a mean arterial pressure of 100mmhg then reaches the beginning of the afferent arteriole with a 85mmhg pressure and the end of it with 60mmhg pressure

Renal Blood Flow (RBF)

❖ Defined as the volume of blood entering both kidneys per unit time.

Kidneys are small (150gm each), yet they receive the highest blood supply in the body; out of the 5L/m cardiac output, 1250 ml goes to both kidneys that is 25% of the cardiac output

However, unlike other tissues, O2 and nutrients concentrations do not decrease significantly as the blood leaves the kidneys.

Renal Plasma Flow (RPF)

Renal Plasma Flow equals 55% of the blood flow (assuming that hematocrit is 45%) this equals 650 ml roughly, so 650 ml of plasma enters the kidney every minute and 649 ml leaves the kidney and only 1 ml is extracted as urine each minute

So urine output is 1ml/minute = 60ml/hr = almost 1.5 liters per day

Although 650 ml/m of plasma enters the glomerulus → only 125 ml/m is filtered, so the filtration fraction is 20%

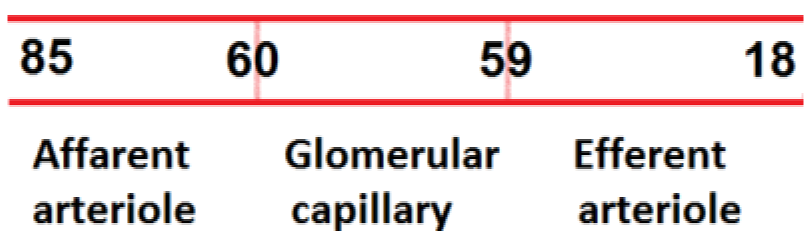
Glomerular Filtration Rate (GFR) is the volume of plasma filtered from the glomerular capillaries to Bowman's capsules per unit time which equals 125 ml/m in male adults

We us GFR as a tool to tell us how much kidney function we have, and we classify kidney failure into 4 stages according to GFR:-

- 50-100% decrease renal reserve (homeostasis is perfectly controlled, so 1 million nephrons are enough)
- 20-49% Renal insufficiency
- 5-19% Renal failure (survive with some modifications and medicines)
- >5% End stage renal failure (without transplantation or hemodialysis the patient cannot survive)
  ** 100% equals 125ml per minute

In some capillaries (like skeletal muscles) we have filtration at the arterial end and reabsorption at the venous end, in intestines we have only absorption while here in the glomerulus we have only filtration; this filtration is governed by Starling forces

Starling Forces



1- **Pc**: the hydrostatic pressure generated by the pumping force of the heart. It averages 60 mm Hg in the glomerular capillaries
**Note that Pc decreases markedly as blood passes through the arterioles, indicating high blood flow resistance in these vessels

This force favors filtration

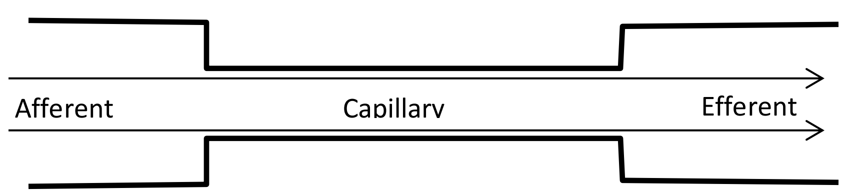
2- **πc**: the colloid osmotic pressure generated by the impermeable proteins in the plasma (not caused by the electrolytes as they are freely permeable). Since 20% of plasma passing through the capillary is filtered, impermeable proteins concentration increases as they pass along the length of the capillaries from 28 mmHg to 36 mm Hg. Thus, the average πc is approximately 32 mm Hg
This force opposes filtration

3- **Pi**: the hydrostatic pressure generated by the interstitial fluid. It averages 18 mm Hg in the Bowman's space
This force opposes filtration

4- **πi**: the colloid osmotic pressure of the interstitial fluid. Since filtered plasma is free of proteins, it equals zero.

A hydrostatic pressure of 60 mmHg is so high compared to other parts of the body and this driving force makes the filtration rate here equals 10 times the filtration rate in all other capillary beds; in all other parts of the body 20L is filtered per day while in the kidney 180L is filtered per day. Also, the permeability is extremely high in the kidney; glomerular capillaries are 400 time more permeable than other capillaries.
** remember the filtration is a flow, and a flow is dependent on the driving force and the permeability

Now how can we control the Pc in the glomerulus?



- Afferent dilatation causes more blood to come to the capillary which increases the hydrostatic pressure

- Afferent constriction causes less blood to come to the capillary which decreases the pressure
  So any drug that cause constriction in the afferent arteriole changes the GFR and might destroy the kidney
- Efferent constriction increases the blood pressure in the capillary but too much constriction will decrease the GFR

<u>Question</u>: In capillary beds of the body, why does the osmotic pressure does stay the same in arterial and the venous end although water is filtered which should increase the concentration of proteins in the venous end and thus the osmotic pressure?

The heart pumps 5 L/minute, 1 L is for the kidneys and the remaining 4L is for the rest of the body almost 2L is plasma being pumped. This equals about 4000L of plasma being pumped by the heart to the capillaries in the body (without kidneys), and only 20L is filtered per day (also some of them is reabsorbed) which too little to causes a difference in the concentration of the proteins between arterial and venous ends

However, in the kidney 20% of plasma is being filtered which is enough to cause a difference between the afferent and the efferent arterioles; that's why it starts with 28mmHg and increases to 36 mmHg (average is 32 mmHg)
**at a certain concentration of albumin in the blood, its relationship with the osmotic pressure stops being linear, but instead and further increase in the concentration will increase the osmotic pressure more than it is expected to do. The same happened here; when high filtration happened we reached a high concentration of proteins which caused a higher than expected increase in the osmotic pressure

DON'T LET IT BREAK YOU, NO MATTER HOW HARD IT GETS.