Reabsorption and secretion along different tubular segments

1-Proximal convoluted tubules (PCT):

<u>I-Reabsorption of:</u>

A- 67 % of filtered sodium, water.
K and Calcium
Most of HCO3-
And slightly less load of filtered chloride.

B-All filtered glucose and amino – acids in early PCT.

C-In first half of PCT ,Na+ is reabsorped by CO transport with glucose and amino - acids.

In second half Na+ is reabsorbed with CL ion because its concentration increases due to water Reabsorption.

The tubular fluid remains iso –osmolar along the PCT.

II-Secretion of.

a-Organic acids and bases which result from metabolism e.g bile salts and oxalates.
b-Secretes catecholamines and some drugs e.g pencillin.

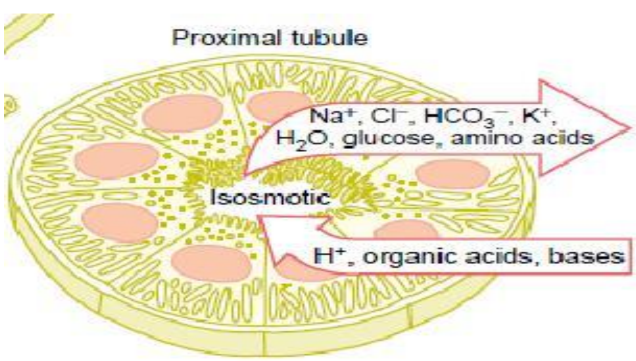

Figure (18): Transport characteristics of the proximal tubule.

2-The loop of Henle:

a-Thin descending segment.

Formed of simple epithelial lining.

Allow simple diffusion of H_2O and solutes.

Highly permeable to H_2O but moderetaly permeable to solutes.

10 % of filtered water is reabsorbed in this part so osmolarity is too much increased by the end of this segment.

The descending limb of loops of Henle receive isotonic fluid from the proximal convoluted tubules.

Their walls are highly permeable to H_2O and less permeable to NaCl so water diffuses freely from tubular lumen outwards by the high osmolarity of medullary interstatium.

Net result:

Tubular fluid become hypertonic and this hypertonicity increases gradually as it moves downward.

Maximal hypertonicity occurs at its bend reaching in humans to about 1200-1400 milliosmols.

b-Thin ascending segment.

Less absorptive capacity for solutes.

Na^+ is absorbed passively after CL^- Reabsorption.

It is impermeable to water.

c-Thick ascending segment.

It is thick epithelium with signs of activity.

Reabsorption of.

27 % of filtered Na^+

20 % of filtered K^+

27 % of filtered Ca^{+2}

The luminal cell membrane contains Na^+ - K^+ - 2 CL transporter.

It is impereabile to water so osmolarity decreases due to Reabsorption of Na^+ and K^+ and Ca^{+2} to become hypotonic (having osmolarity of 100 – 200 milliosmoles) on reaching the distal convoluted tubules.

3-The distal convoluted tubules:

<u>It consists of.</u>

<u>a-The early diluting segment.</u>

Has the same characters as thick ascending limb of loop of Henle.

<u>b-Late distal tubule and cortical collecting tubule.</u>

They have the same characters and contain two types of cells.

<u>1-The principal cells.</u>

Responsible for K+ secretion

<u>2-The intercalated cells.</u>

Secretes H+ and reabsorbs K+ in case of K+ depletion.

<u>Characters of both segments.</u>

1-Reabsorbes sodium and secretes K+ under influence of aldosterone hormone.

2-Secretes H+ via primary active transport by H+ pump ,that can transport H+ against gradients up to 1000 folds.

3-Water Reabsorption under the influence of ADH.

4-Impermeable to urea.

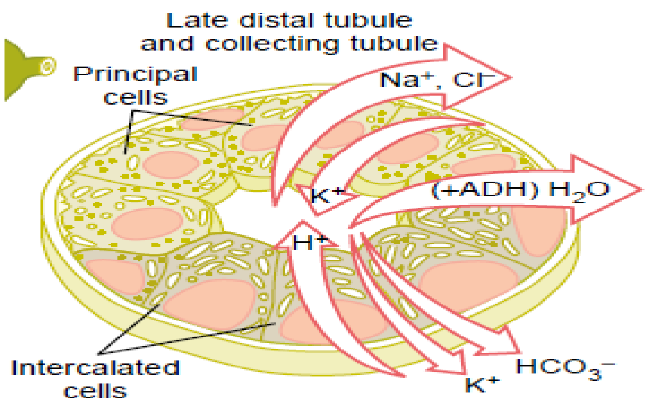

Figure (20): Transport characteristics of the late distal tubule and collecting tubule.

<u>4-Medullary collecting duct.</u>

It has the same characters as distal nephron except it is permeable to urea and ADH increases this permeability.

<u>The transport via distal tubules differ from proximal tubule in the following.</u>

A-Proximal tubules has a large capacity so reabsorb large quantities of salt and water, while distal tubules has a smaller capacity, it can reabsorb 9% of filtered sodium and 19 % of filtered water.

B-Na+ and H2O Reabsorption are closely coupled in proximal tubules because H2O permeability is high ,while in the distal tubules as H2O permeability is variable and low so Na+ and H2O Reabsorption may be uncoupled.

The ability of the kidney to dilute or concentrate urine

<u>The mechanism:</u>

In order to excrete concentrated urine ,the kidney has to increase water Reabsorption by the collecting tubules .

This process needs 2 factors.

1-The action of ADH to open water intracellular channels.

2-**High and stable osmotic gradient in the area surrounding the collecting tubules to maintain high rate of water movement according to osmotic gradient through opened channels. This can be done only by a special mechanism in the renal medulla called** Counter current mechanism.

Steps needed for creation of osmotic gradient.

1-Increaded solute load in the renal medulla by:

a-Active Na+ Reabsorption in the thick ascending limb of loop of Henle followed by passive movement of other solutes e.g CL- and HCO3 .

b-Active Na+ Reabsorption by the collecting tubules.

c-Passive urea Reabsorption by the collecting tubules.(solvent drag*****)

2-Creation of Osmotic gradient by Counter current system.

Definition of counter current system:

It is a system characterized by the presence of:

- U shaped tube with its 2 limbs close to each other.
- Continuous counter current stream.
- A source of energy.

All these characters are found in the loop of Henle as:

- It consists of U shaped tube with 2 limbs are close to each other.
- The tubular fluid flows in the 2 limbs in a counter current stream.
- The source of energy is the active Na+ - K + pump of the thick ascending limb of loop of Henle.

The loop of Henle acts as a **counter current multiplier** which multiply the tonicity of the medullary interstitium about 5 times (from 300m.osm/L at the outer medulla to 1400m.osm/L at the renal papilla).

To understand how the counter current can create an osmotic gradient we have to imagine that this process can occur in successive steps beginning from position Zero as follow:

Position Zero:

We imaging that fluid entering and leaving loop of Henle is Iso-Osmotic with fluid flowing out of proximal tubule = 300 mOsm / L.

Steps:

Ascending limb: is impermeable to water but permeable to solutes, thus its main function is removal of solutes.

Na Cl is transferred to medullary interstitium (M.I) passively in thin part and actively in the thick part.

As the ascending limb is impermeable to water, so tubular fluid inside he ascending limb is hypotonic to M.I (it's 200 m osm/ L less than M.I at any transverse level) so fluid leaving the ascending limb is hypotonic (100 m osm/L). This results in:

1- Hypertonic medullary interstitum in a longitudinal direction from 300 (outer medulla) – 1400 m osm/ L (inner medulla). The tonicity is multiplied about 5 times.
2- Hypotonic fluid leaves medulla: at any transverse level, the osmolarity is 200 m osm/L less than M.I.

Descending limb: is impermeable to Na Cl but permeable to water thus its main function is water removal.

The hypertonic M.I produced by the ascending limb will absorb water from descending limb till the fluid in the descending limb becomes isotonic with M.I at any transverse level. The end of descending limb at renal papilla is 1400 m osm/L.

Preservation of osmotic gradient (the role of vasa recta as a counter current exchanger):

The preservation of osmotic gradient is very important because any osmotic gradient in the medullary tissue could be washed out by the medullary blood flow.

However the blood supply to the medulla (vasa recta) has some characters that help to maintain the solute load and prevent the washout of the osmotic gradient in the medullary tissue.

Vasa recta is a loop of peritubular capillaries, which run close to and parallel to the loop of Henle. It is characterized by.

a-U shaped loop of capillaries.

b-Counter current blood flow.

c-High permeability to water and electrolytes.

d- Low blood flow (0.25 ml / gm tissue / min)

The role of vasa recta in the counter current mechanism is to exchange the Nacl and urea between its 2 limbs so as to keep them in the medullary interstitial fluid as follow:

1-In descending limb of vasa recta water flow out and Nacl flows inside due to increased osmolarity of medullary ISF as blood moves deep in the medulla.

2-In ascending limb ,and as osmolarity decreases gradually toward the cortex H2O moves again to inside the ascending limb ,while Nacl and urea moves out in the medullary interstatium.

The net result of the above 2 points osmolarity is kept constant in the medullary interstatium.

The function of vasa recta as a counter current exchanger is to maintain renal medullary hyperosmolority through:

1-Trapping of solutes (Nacl and urea) in renal medulla.

2-removing excess water from medullary interstitium

By:

Walls of vasa recta are highly permeable so allowing passive diffusion of water and solutes

In their descending limbs:

The solutes diffuse (Nacl and urea) from medullary interstatium into the vessel because its concentration is higher than blood so diffuses according to concentration gradient into vasa recta.

At the same time water diffuses out into medullary interstitiatium because.Osmolority of Medullary interstatium exceeds that of blood .

Net result:

Blood become gradually concentrated as it moves downward until an osmotic pressure of 1200 mOsm at the tip.

In ascending limb:

Solutes diffuses from blood into the medullary interstatium as osmolarity in the interstatium gradually decrease.

H2O moves from interstatium to the blood again.

Nacl and urea moves out of the ascending limb to the Medullary interstatium.

Net result:

The blood flows out of the medulla carries no solutes but only a small amount of excess water, which is absorbed by the renal tubules in the medulla, thus Osmolority is kept constant in medullary interstatium.

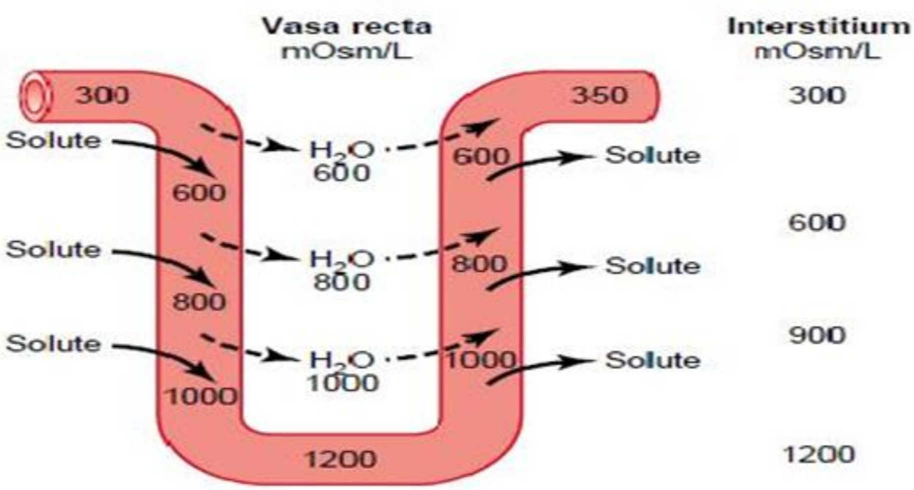

Figure (22): vasa recta as a counter current exchanger.

Role of urea in urine concentration:

Urea plays an important role in the concentrating ability of the kidney. It shares in 45-50% of osmolarity of M.I.

This can be explained by the following steps:

Step (1)

Concentration of urea in the tubular fluid increases gradually as most renal tubules are impermeable to urea (ascending limb of L.H, DCT, cortical CD and outer medullaryCD),while water and other solutes are absorbed in large amounts along renal tubules.

Step (2)

Concentration of urea reach its maximum level in the late <u>**collecting duct**</u> (inner medullary collecting duct)which is highly permeable to urea in the presence of (ADH), so urea is passively reabsorbed according to concentration gradient.

Step (3)

Absorption of urea in this segment adds much to the osmolarity of lower medulla, which in turn increases the rate of H2O Reabsorption by descending limb of loop of Henle so increasing NacL concentration in the tubular fluid that reach ascending limb. Urea diffuses from M.I. to the thin ascending limb and to the descending limb of L.H till reaches inner medullary collecting duct to be reabsorbed again by ADH which is known as **urea trapping** or **urea cycling**.

Step (4)

When NaCL rich fluid reach the ascending limb which is permeable to NaCL, passive NaCL Reabsorption occurs increasing the solute load in the renal medulla.

Role of ADH in formation of concentrated urine:

ADH plays a key role in urine concentration by:

1- Increase CD permeability to water along osmotic gradient of M.I.
2- Increase urea reabsorbtion passively from inner medullary CD.
3- V.C of the efferent arteriole which lead to:
    a- increase osmolarity of M.I. by decrease washing out of solutes from it.
    b- Increase the filtered load of Na+ leading to increase Na+ reaching to ascending limb of L.H. and more removal of Na+ from ascending limb to M.I adding to the hypertyonicity of M.I.