Renal Block

Physiology Team

2nd Lecture

Regulation of glomerular filtration

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❖ Principal of urine formation :

1. Filtration (glomerulus)
2. Absorption and secretion i.e modification (tubule).

Glomerular Filtration

During filtration , large quantities of water and solutes pass through the filtration membrane from the blood into the glomerular capsule.

❖ Basic Mechanisms of Urine Formation :

1. Glomerular filtration
2. Reabsorption
3. Secretion
4. Urine concentration

- **Glomerular Filtration** :
  - Plasma ultrafiltration (filtration of small molecules) Ultra means small.
  - Composition of filtrate (same as plasma except plasma protein) All components of the plasma are filtered except protein.

(Note: Be careful that: There will be no RBCs or WBCs in the filtrate because only plasma is filtered).

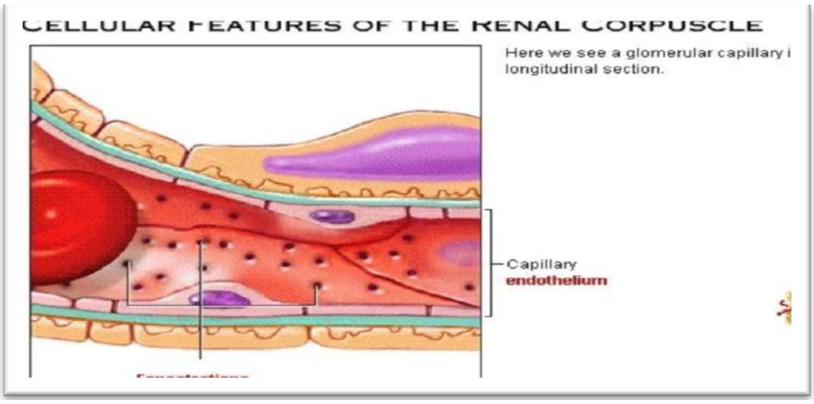
  - Isotonic (~300 mosmo/l) (Same osmolality like the plasma)
  - Composition
    - Water
    - Electrolytes
    - Glucose
    - Urea
    - Creatinine

Note: until here the name is filtrate not urine

- **Filtration membrane :**
  - Filtration membrane (3 layers).
    - Capillary endothelial.
    - Basement layer (contain mesengial cell).
    - Capsule epithelial layer podocytes .
  - Characteristics of filtration membrane :

1-Endothelial layer :

- Fenestration 70-100 nm (pores)

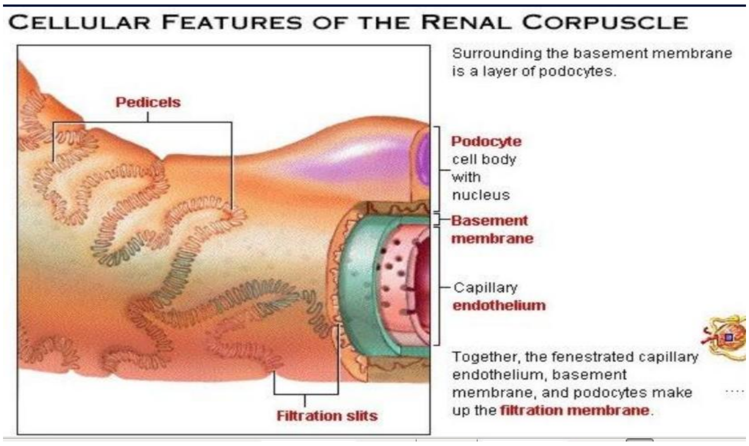


2-Basement membrane:

- Homogenous collagenous fibers with no pores .
- Negative charge (sailoprotein : selective protein gives negative charge ,prevent certain molecules from passing) .
- Contractile mesengial cells (when it contracts, it will decrease the filtration so it will control the size of filtration membrane) .

3- Epithelial membrane :

- Podocytes (the wall consist of projections or podocytes)
- Slit pores 25-60nm



- **Filtration of Molecules**
  1. Molecular size and charge regulate filtration
     - < 4nm freely filtered
     - 4-8 nm: negatively charge poorly filtered compared to neutral & positively charge
     - > 8 nm not filtered

Note: Plasma protein (albumin) is 7 nm so it can pass according to its size, but according to the charge, which is negative , it won't be able to pass

Any disease that effect the –ve membrane will pass albumin→ causing albuminurea as in nephritic syndrome

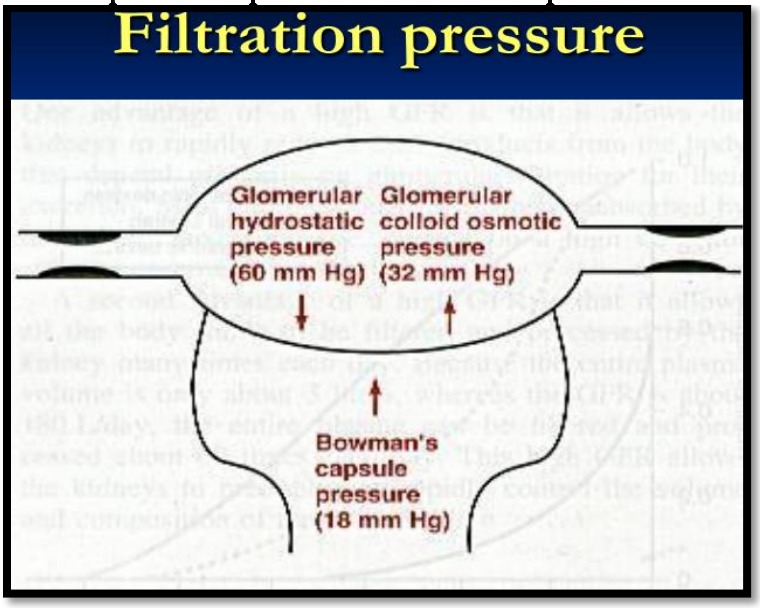
- **Filtration pressure :**
  - Pressure that moves plasma out of the glomerulus capillary into the Bowman capsule space
  - Four different pressures affect filtration
  - The algebraic sum of these pressures is the driving pressure for filtration (to give the net filtration)

Filtration pressure (starling forces)

1. **Glomerular hydrostatic pressure (PGC)**

Pressure of the arteries and arterioles which is generated by the Heart. in other capillaries it has the value of "40" ,but in the kidney it will be more and the magnitude will be 60mmHg due to the demand of high presser to filtrate , and that is the reason behind the location of the kidney" near the abdominal aorta"

2. **Glomerular osmotic pressure (πGC)**
   Pressure of plasma proteins
3. **Bowman hydrostatic pressure (PBS)**" due to presence of fluid in bowman capscule after filtration"
4. **Bowman osmotic pressure (πBS) = zero**
   Because there are no plasma protein in the capsule



Notice that : Glomeular hydrostatic pressure favors filtration " so has +ve charge" , but glomerular colloid oncotic pressure & Boman's capsule pressure opposes filtration " so they have –ve charges"

❖ Starling forces & filtration

1. Hydrostatic pressure (PGC)
   - Favors(cause) filtration
   - 60 mmHg
   - Remain constant along the entire glomerular capillary that mean does not change in any portion

2. Hydrostatic pressure in Bowman space (PBS)
   - Opposes filtration
   - 18 mmHg
   - Due to filtered fluid in the capsule

3. Colloid osmotic pressure in glomerular capillaries (π GC) or
   - Opposes filtration
   - 32 mmHg

- Caused by plasma protein
- Is not constant

  Will increase near the Efferent because the fluid has been filtered so the concentration of plasma protein will increase and according to that the osmotic will increase and the filtration will deacrese

4. Colloid osmotic pressure in Bowman capsule (π BC)
   - Zero (no plasma protein)

❖ Calculation of net filtration pressure

- **Net filtration pressure :**

  = 60-18-32= 10 mmHg (if the net filtration is higher than 10 mmHg it will to will lead to dangerously higher filtration)

  = Kf (PGC - PBS) - (π GC - πBS)

  - Kf : Filtration coefficient depend on Filtration membrane
    - permeability
    - Surface area

      If Kf decreases the filtration will decrease
  - Glomerular permeability > 100 x skeletal capillaries permeability

- **Net filtration pressure :**

- Net filtration pressure decreases as passing along the glomerular capillary this due the fact
- Only plasma is filtrated → ↑ plasma protein conc. → ↑ oncotic pressure → ↓ net filtration pressure

- **Glomerular filtration rate**

- Amount of plasma filtered by all nephrons in both kidneys/unit time
- 125 ml/min if its value drop below 90 that mean there problem in kidney function
- Kidney function test
- Variation in GFR between different species depend on numbers of nephrons

For information:

Uin= concentration of inulin in the urine

Measurement of GFR :

Characteristic of substance used

- **Freely filtered (not reabsorbed or secreted)**
- **Not metabolized by the kidney**
- **Not toxic and stable**
- **Not bound to plasma protein**
- **Does not change renal plasma flow**
- **Inulin**

Test procedure

- **Intravenous loading dose of inulin followed by intravenous infusion of inulin to maintain plasma level constant**
- **Urine is collected for 15 or 20 min, to measure inulin concentration in urine and urine volume**
- **Blood sample is taken half way of urine collection to measure inulin concentration**

❖ Calculation of GFR

- The amount of inulin excreted = Uin x Uv
- The amount of inulin filtered = Pin x GFR
- As inulin is not reabsorbed or excreted both quantity are equal
- Pin x GFR =Uin x Uv
- GFR = $\frac{\text{Uin x Uv}}{\text{Pin}}$ = ml\min

❖ Calculation Of GFR & FF

- GFR= K_f x net filtration pressure
- GFR = 12.5 x 10 = 125 ml/min
- $K_f \propto$ GFR (↓ K_f in diabetes - ↓ GFR) directly proportional

  In diabetes there is change in surface area and permeability

Uv = urine volume
Pin = concentration of inulin in the plasma
GFR= amount of plasma filtered by each kidney/min

❖ Filtration fraction

- The fraction of renal plasma flow that is filtered = GFR/RPF
- 125/ 625= .2= 20%

❖ Factors affecting GFR

1. Changes in PGC
- PGC ∝ GFR
- Systemic blood pressure
- afferent vasoconstriction - ↓ PGC -↓GFR
- Efferent vasoconstriction ↑ PGC - ↑GFR

2. Changes in πGC
- πGC 1/∝ GFR
- ↑ πGC - ↓ GFR
- hemo concentration (dehydration) - ↑ plasma protein concentration ↑ πGC
- ↑ filtration fraction- ↑ πGC

3. Changes in PBS
- P_{BC} 1/∝ GFR
- ↑ P_{BC} due to obstruction to outflow - ↓ GFR
- urethral obstruction
- kidney edema

4. Changes of filtration coefficient
- glomerular capillary permeability
- Changes in surface area

5. Changes in renal blood flow