RENAL FUNCTIONS & GFR

Renal Block
Objectives

- Enumerate general functions of the kidney
- Identify and describe that the nephron is the structural and function Unit of the kidney
- Explain glomerular filtration membrane & filtration forces
- Describe mechanism of filtration & composition of the glomerular filtrate
- Calculate the net filtration pressure using parameters of Starling forces

Key Words

nephron, glomerular filtration, tubular reabsorption and tubular secretion, capillary hydrostatic pressure, glomerular filtration membrane, filtrate.

Color index

What was written with gray is less important

Abbreviations

RBF = Renal Blood Flow
GFR = Glomerular Filtration Rate
JGA = Juxtaglomerular apparatus
**THE FUNCTIONS OF THE KIDNEY**

1- Regulation of...
   - water and electrolyte balance
   - body fluid osmolality & electrolytes
   - acid/base balance
   - arterial blood pressure.

2- Excretion of...
   - waste products (UREA, CREATININE, URIC ACID).
   - Detoxification and excretion of drugs.

3- Biosynthesis
   - activation of vitamin D
   - Erythropoietin production
   - Renin formation
   - glucose from amino acids during prolonged fasting. (gluconeogenesis)

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**NOTE**

1) Therefore, the patients who have renal failure will have recurrent fractures due to decrease synthesis of Vit D (treatment by : injection Vit D)

2) Therefore, the patients who have renal failure will have anemia (treatment by : injection erythropoietin)

3) Released by Juxtaglomerular apparatus
NITROGENOUS WASTES

Measurement of nitrogen wastes within serum help to assess the kidney function

Glomerular filtration: Filtration of fluid from glomerular capillaries into the renal tubules.

1. Glomerular filtration
2. Tubular reabsorption
3. Tubular secretion
4. Excretion

The functional & structural unit of the kidney:
The nephron
- Each kidney has 1 million nephrons, each nephron is capable of urine formation.
- Located in both the cortex and medullary areas

Urine formation steps:

- Creatinine
- Uric acid
- Urea

Proteins -> Amino acids
\( \text{NH}_2 \) removed -> Forms ammonia
Liver converts to urea
Glomerulus: capillary tuft: in which large amount of fluid is filtered from blood.

Bwaman’s capsule: Around the glomerulus and receives the filtrate.

Glomerular filtrate collects in capsular space, flows into renal tubule.

Tubules: in which filtered fluid eventually is converted into urine.

Review of the Structure of a nephron

Types of nephrons:

<table>
<thead>
<tr>
<th>Types of nephrons</th>
<th>Cortical nephrons</th>
<th>Juxtamedullary nephrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence</td>
<td>85%</td>
<td>15%</td>
</tr>
<tr>
<td>glomeruli loc.</td>
<td>in the outer portion of cortex</td>
<td>in inner part of the cortex</td>
</tr>
<tr>
<td>loops of Henle.</td>
<td>Short loop</td>
<td>long loops extended into the medulla.</td>
</tr>
<tr>
<td>Conc. Of urine</td>
<td>Diluted urine</td>
<td>Concentrated urine (because it maintains salt gradient, helps conserve water)</td>
</tr>
</tbody>
</table>

* Proximal convoluted tubules has blind end that forms the Bowman’s capsule.
Renal blood flow to the kidney represents 20% of cardiac output. The blood flows to each kidney through a renal artery.

**Features of renal circulation:**

- High blood flow rate (1200 ml/min).
- Presence of two capillary beds:
  1. **Glomerular:** take place in filtration of fluid and solutes.
  2. **Peritubular** take place in reabsorption and secretion

*Efferent* and *afferent* arterioles are major sites of renal resistance.\(^{(1)}\)

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Urinary excretion rate = Filtration rate – (reabsorption + secretion).

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**NOTE**

(1) because they have vascular smooth muscle cells which constricted and vasodilated in response to change in blood pressure.
Glomerular filtration

**Definition**
It is the filtration of fluid from the glomerular capillaries into the renal tubules.

filtration of body fluid and blood from high molecular weight and negatively charged through glomerular capillaries to renal tubules.

**GFR (Glomerular filtration rate)**

<table>
<thead>
<tr>
<th>normally</th>
<th>125 ml/min</th>
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<tbody>
<tr>
<td>=</td>
<td>20% renal plasma flow.</td>
</tr>
</tbody>
</table>

**Substances**
It contains all substances present in plasma except RBC’s & proteins.
Albumin does not normally pass as they are repelled by the negative charge of the proteneaceuos material of basement membrane.

Example of proteins: fibrinogen and albumin

**Consisting of three layers:**

- Single layer of capillary endothelium.
- Single epithelial lining of Bowman’s capsule (Podocytes)
  During filtration the fluid moves between their foot processes (pseudo-podia).
- Basement membrane between endothelium and epithelium.

**Molecular size**
Allow passage of molecules up to 70,000 diameter
### Table of Renal Corpuscle Structure

<table>
<thead>
<tr>
<th>Name of the structure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Renal corpuscle</td>
<td></td>
</tr>
<tr>
<td>B Proximal tubule</td>
<td></td>
</tr>
<tr>
<td>C Distal convoluted tubule</td>
<td></td>
</tr>
<tr>
<td>D Juxtaglomerular apparatus</td>
<td></td>
</tr>
<tr>
<td>1. Basement membrane (Basal lamina)</td>
<td></td>
</tr>
<tr>
<td>2. Bowman's capsule – parietal layer</td>
<td></td>
</tr>
<tr>
<td>3. Bowman's capsule – visceral layer</td>
<td></td>
</tr>
<tr>
<td>3a Pedicels (Foot processes from podocytes)</td>
<td></td>
</tr>
<tr>
<td>3b Podocyte</td>
<td></td>
</tr>
<tr>
<td>4. Bowman's space (urinary space)</td>
<td></td>
</tr>
<tr>
<td>5a. Mesangium – Intraglomerular cell</td>
<td></td>
</tr>
<tr>
<td>5b. Mesangium – Extraglomerular cell</td>
<td></td>
</tr>
<tr>
<td>6. Granular cells (Juxtaglomerular cells)</td>
<td></td>
</tr>
<tr>
<td>7. Macula densa</td>
<td></td>
</tr>
<tr>
<td>8. Myocytes (smooth muscle)</td>
<td></td>
</tr>
<tr>
<td>9. Afferent arteriole</td>
<td></td>
</tr>
<tr>
<td>10. Glomerulus Capillaries</td>
<td></td>
</tr>
<tr>
<td>11. Efferent arteriole</td>
<td></td>
</tr>
</tbody>
</table>

**Diagram of renal corpuscle structure:**

- **A** Renal corpuscle
- **B** Proximal tubule
- **C** Distal convoluted tubule
- **D** Juxtaglomerular apparatus

**Diagram Key:**
- **1.** Basement membrane (Basal lamina)
- **2.** Bowman's capsule – parietal layer
- **3.** Bowman's capsule – visceral layer
- **3a** Pedicels (Foot processes from podocytes)
- **3b** Podocyte
- **4.** Bowman's space (urinary space)
- **5a.** Mesangium – Intraglomerular cell
- **5b.** Mesangium – Extraglomerular cell
- **6.** Granular cells (Juxtaglomerular cells)
- **7.** Macula densa
- **8.** Myocytes (smooth muscle)
- **9.** Afferent arteriole
- **10.** Glomerulus Capillaries
- **11.** Efferent arteriole

**NOTE:**
Hopefully this illustration will help you to understand the Glomerular membrane and will help you throughout the block. This picture is just for your understanding 😊.
Juxtaglomerular apparatus JGA

<table>
<thead>
<tr>
<th>Structures make JGA</th>
<th>Description</th>
<th>Function in the apparatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- juxtaglomerular cells (Granular cells)</td>
<td>Specialized smooth muscle cells in the wall of the afferent arteriole have mechano-receptors for blood pressure.</td>
<td>Synthesize, store, and secrete the enzyme renin.</td>
</tr>
<tr>
<td>2-Macula densa</td>
<td>an area of closely packed specialized cells lining the distal convoluted tubule.</td>
<td>Sensitive to the concentration of sodium ions in the fluid.</td>
</tr>
<tr>
<td>3-extraglomerular mesangial cells</td>
<td>outside the glomerulus, between the macula densa and the afferent arteriole</td>
<td>The specific function of mesangial cells is not well understood, although it has been associated with the secretion of erythropoietin</td>
</tr>
</tbody>
</table>

these structures are in contact they form the monitoring structure called the juxtaglomerular apparatus
Glomerular Filtration Rate (GFR) + Forces controlling GFR: Starling’s forces

Determined by:

- The glomerular capillary filtration coefficient (Kf) = 12.5
- The net filtration pressure across the glomerular capillaries.

GFR = Kf x Net filtration pressure.

1. permeability
2. surface area of filtration barrier

99% of filtrate reabsorbed

1 to 2 L urine excreted

Starling’s forces:

<table>
<thead>
<tr>
<th>Glomerular hydrostatic pressure</th>
<th>( P_{\text{BLOOD}} )</th>
<th>= 60 mmHg</th>
<th>It promotes filtration.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrostatic pressure in Bowman’s capsule</td>
<td>( P_{\text{FILTRATE}} )</td>
<td>= 18 mmHg</td>
<td>It opposes filtration.</td>
</tr>
<tr>
<td>Colloid osmotic pressure of glomerular plasma proteins</td>
<td>( \pi )</td>
<td>= 32 mmHg</td>
<td></td>
</tr>
<tr>
<td>Net filtration pressure</td>
<td>( P_{\text{NET}} )</td>
<td>60-(18+32)= 10 mmHg</td>
<td></td>
</tr>
</tbody>
</table>
How changes in Forces determining GFR affect GFR?

**Changes in Glomerular pressure**

**INCREASE IN…**

A- Bowman’s capsule pressure which happen in urinary obstruction:
1. Stones
2. Tumors

B- Glomerular capillary colloid osmotic pressure

**INCREASE IN…**

C- Glomerular capillary hydrostatic pressure
Which is affected by:
1. ABP.
2. Afferent arteriolar resistance. (DECREASE filtration)
3. Efferent arteriolar resistance (increase filtration)

**How GFR is affected?**

- **↓ GFR**
  - Afferent vasoconstriction
  - Efferent vasoconstriction

**vasodilation and vasoconstriction of the afferent and efferent arterioles alter the blood flow through the glomerular capillaries, there are corresponding alterations in the glomerular filtration rate (GFR).**

<table>
<thead>
<tr>
<th>Afferent vasoconstriction</th>
<th>Efferent vasoconstriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ Resistance</td>
<td>↑ Resistance</td>
</tr>
<tr>
<td>↓ RBF</td>
<td>↓ RBF</td>
</tr>
<tr>
<td>↓ GFR</td>
<td>↑ GFR</td>
</tr>
</tbody>
</table>
Factors affecting Renal blood flow and GFR

1. Hyperglycemia
2. Fever

1. Sympathetic stimulation of renal arterioles
2. Norepinephrine
3. Aging

High protein diet → ↑ amino acids → ↑ filtrate

Angiotensin II (. It constricts efferent arteriole more than afferent)
**Multiple choice Questions**

**Q1:** The pressure in the glomerular capillaries is high because of the resistance to flow provided by the

- a. Afferent vasoconstriction
- b. Efferent vasoconstriction
- c. Both A&B

**Q2:** A blockage in urine outflow (perhaps due to nephrolithiasis) causes an increase in the pressure in Bowman’s space. How would this affect net glomerular filtration pressure and GFR?

- a. Decrease
- b. Increase
- c. Nothing changes

**Q3:** The mean arterial pressure increases from 90 mmHg to 110 mmHg. What happens to prevent an increase in the pressure in the glomerular capillaries?

- a. Constriction of afferent arteriole
- b. Constriction of efferent arteriole
- c. Dilation of efferent arteriole
- d. Both A or C

**Q4:** Renal blood flow to the kidney represents how much of cardiac output?

- a. 12%
- b. 15%
- c. 20%

**Q5:** In response to hemorrhage, which of the following is activated to decrease GFR?

- a. ANP Secretion
- b. Renal autoregulation
- c. Proteinuria
- d. Sympathetic nervous system

**Q6:** Which ONE of the following cause an increase in GFR only?

- a. High protein diet
- b. Hyperglycemia
- c. Angiotensin II

**Q7:** If the hydrostatic pressure in Bowman’s capsule is 18 mmHg and glomerular hydrostatic pressure is 70 mmHg while the colloid osmotic pressure is 32 mmHg. How much is the net filtration pressure across the glomerular capillaries?

- a. 10 mmHg
- b. 20 mmHg
- c. 30 mmHg

**Q8:** From the previous question, knowing the net filtration pressure across the glomerular capillaries, how much is the GFR?

- a. 125 ml/min
- b. 250 ml/min
- c. 375 ml/min

**Answers:** Q1-b ..... Q2-a ..... Q3-d ..... Q4-C

**Answers:** Q5-d ..... Q6-a ..... Q7-b ..... Q8-b