Renal Function Test

Department of Biochemistry
Anatomy of Kidneys

**Definition:** Pair of excretory organs situated on the posterior abdominal wall

**Location:** $T_{12}$ to $L_{3}$

**Hilum:** Renal rein, renal artery, renal pelvis

**Capsule:** Protects the kidney
Components of the Functional part of the Kidney (Nephron)

Glomerulus:

The glomerulus has a semi-permeable membrane, through which substances except cells and large molecular size plasma proteins are filtered into Bowman’s capsule at the rate of 120 ml/min

• This is known as Glomerular Filtration Rate
Proximal Convoluted Tubule:
Approximately 80% of salt and water are reabsorbed here.

Loop of Henle:
Descending limb $\rightarrow$ Permeable to water; passive reabsorption of water occurs.

Ascending limb $\rightarrow$ impermeable to water; actively reabsorbs Na$^+$ and Cl$^-$
Distal Convoluted Tubule:

Filtered water and solutes are reabsorbed here.

Collecting Duct:

ADH controls the water permeability of the collecting tubule.

<table>
<thead>
<tr>
<th>Renal Threshold</th>
<th>Tubular Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma level above which the compound is excreted in urine.</td>
<td>Maximum capacity of kidneys to absorb a particular substance.</td>
</tr>
<tr>
<td>Eg: Glucose: 180 mg 1 dl</td>
<td>Eg: Glucose: 375 mg 1 min</td>
</tr>
</tbody>
</table>
Functions of Kidney

• Maintenance of Homeostasis
• Excretion of Metabolic end products
• Elimination of Foreign materials
• Regulation of Acid – base balance
• Retention of vital substances
• Regulation of arterial pressure
• Production of Hormones:
  ➢ Erythropoietin
  ➢ Calcitriol
  ➢ Renin
Assessment of Renal Function

- To identify renal dysfunction
- To diagnose the renal disease
- To monitor the progression of renal disease
- To monitor the response to treatment
Classification of Renal Function Test

I. Urine Analysis
   Physical Examination
   Chemical Examination
   Microscope Examination

II. Blood Analysis
   Estimation of Plasma proteins
   Estimation of NPN
III. Tests for Glomerular Function

Creatinine clearance
Urea clearance
Inulin clearance

IV. Test to Measure RPF

PAH Test

V. Test for Tubular Function

Urine concentration test
Urine dilution test
Acid load test
Phenol – sulphophthalein test
I. Urine Analysis

Physical Examination

Urinary Output Volume: 1,500 ml / day

(a) Polyuria → 2,500 ml / day
   Diabetes Mellitus
   Diabetes insipidus
   Chronic glomerulonephritis

(b) Oliguria → 500 ml / day
   Fever
   Diarrhea
   Acute renal failure

(c) Anuria → Complete cessation of urine
   Acute tubular Necrosis
   Bilateral renal stones
   Prostate enlargement
(ii) **pH:**

Urine is normally acidic with a pH of 4.5 to 6.0

Alkaline urine is found in cases of UTI

(iii) **Specific Gravity:**

1.010 to 1.025

Indicates the concentrating ability of kidney

(iv) **Osmolality:**

Urine osmolality depends on the state of hydration. After excessive fluid intake the osmotic concentration may fall as low as 50 m osm/kg, whereas with restricted fluid intake, it is up to 1,200 m osm/kg.

On average fluid intakes, 300 to 900 m osm / kg are found.
(v). Colour:

Urine is transparent, pale yellow (or) amber in colour.

(vi). Odour:

Fresh urine is normally aromatic.
Foul smell indicated bacterial Infection.
Chemical Examination

(i) **Glucose:**

Normal urine contains small amounts of glucose, which cannot be detected by routine test.

Presence of detectable amounts of glucose in urine is called glycosuria.
• **Protein:**
  
The glomerular basement membrane does not usually allow passage of albumin and large proteins.

  Increased amounts of protein in urine is called proteinuria.

  **Proteinuria – Indication of leaky glomerulli.**

  Most common type of proteinuria is due to albumin.
(iii) **Blood:**

Intact glomerulus does not allow the passage of RBC’s
But, with severe glomerular damage, RBC leakage occurs – Hematuria.

iv. **Ketone Bodies:**

Presence of ketosis can be established by detection of ketone bodies in urine using Rothera’s test, strip tests are also available.
Microscopic Examination

- Urine sample is collected
- Subjected to centrifugation
- Microscopic Examination of the centrifuged Urinary sediment defects the following.
  (i) Cells – RBC, WBC, pus cells
  (ii) Crystals – Calcium phosphate, Calcium oxalate, Amorphous phosphate
  (iii) Casts – Hyaline casts, granular casts, Red blood casts.
Estimation of Blood

Estimation of Plasma Proteins:

Normal Value : 6.4 to 8.3 gm%

Components :

(i) Albumin : 3 – 5 gm%
(ii) Globulin : 2 – 3 gm %
(iii) Fibrinogen : 0.3 gm%

A/G ratio : 1.7:1
Estimation of Non - Protein Nitrogenous Substances

Normal Value : 28 to 40 mg%

Components:

(i) Urea : 20 to 40 mg%
(ii) Uric acid : 2 to 4 mg %
(iii) Creatinine : 0.6 to 1.2 mg%

→ Normal blood levels of these substances are ↑sed in case of impairment of renal function.

→ An Increase of these end products in blood - Azotaemia.
Tests for Glomerular Function
Renal Clearance Tests

• A renal clearance test is employed to assess the rate of glomerular filtration.

• Renal clearance is defined as the volume of plasma from which the substance is completely cleared by the kidneys per minute. (ml/min)

\[
\text{Clearance} = \frac{\text{U} \times \text{V}}{\text{P}}
\]

→ Where, \( \text{U} \) - Concentration of substance in urine (mg/dl)
\( \text{V} \) - Volume of urine excreted (ml/min)
\( \text{P} \) - Concentration of substance in plasma (mg/dl)
<table>
<thead>
<tr>
<th>Substance used for Clearance Tests</th>
<th>Criteria for choosing the Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endogenous creatinine &amp; urea</td>
<td>Freely filtered</td>
</tr>
<tr>
<td>Exogenous Inulin</td>
<td>Should not be reabsorbed or secreted.</td>
</tr>
</tbody>
</table>
Creatinine Clearance Test

(i) Creatinine is an excretory product derived from creatine phosphate.
(ii) This conversion is spontaneous and non-enzymatic.
(iii) Creatinine is an ideal substance for clearance test:

Since, it is already present in body fluids, it’s plasma concentration is steady throughout the day.

No need for intravenous administration as it is produced endogenously.

Freely filtered and not reabsorbed.
(iv) Creatinine clearance is defined as the routine of plasma completely cleared of creatinine per minute.

(v) 24hr urine sample plasma concentration – Estimated

(vi) Directly related to the GFR. Hence, its measurement is used to assess the renal glomerular function.

Creatinine clearance = GFR = $\frac{U \times V}{P}$
Where,

\[ U \rightarrow \text{Urine concentration of creatinine (mg/dl)} \]
\[ V \rightarrow \text{Volume of urine (ml/min)} \]
\[ P \rightarrow \text{Plasma concentration of creatinine (mg/dl)} \]

(vii) Normal value : 90 – 120 ml/min

(viii) ↓sed creatinine clearance indicates ↓se GFR
Urea Clearance Test

(i) End product of protein metabolism

(ii) Less sensitive than creatinine clearance because:

- Partially reabsorbed
- Increased by dietary protein

Urea clearance \( C_m = \frac{U \times V}{P} \)

(iii) Normal Value : 75ml/min
Inulin Clearance Test

(i) Polysaccharide of fructose
(ii) Neither reabsorbed nor secreted
(iii) Ideal substance to measure GFR

(iv) Disadvantages:
   Need for intravenous administration
   Technical difficulty of the analysis

(v) Concentration of Insulin
   Volume of urine excreted
   \[ GFR = \frac{U \times V}{P} \]

(vi) Normal Value : 120ml/min.
IV. Test To Measure Renal Plasma Flow

Para – Aminohippurate Test

(i) PAH: Filtered and secreted
(ii) Not reabsorbed
(iii) PAH clearance is defined as the amount of plasma passed through kidneys.
(iv) Known amount of PAH is injected into the body
(v) Concentration of PAH in plasma and urine volume of urine Excreted.

\[ \text{RPF} = \frac{U \times V}{P} \]

(vi) Normal Value : 700ml/min
V. Test For Tubular Function

**Urine Concentration Test:**

(i) Fluid intake is withheld for 15 hours.
(ii) Early morning urine sample is collected.
(iii) Specific gravity is measured.
(iv) If specific gravity exceeds 1.025, the renal concentrating ability is considered normal. If not, indicates renal impairment.
(v) Clinically, the loss of concentrating ability is manifested by nocturia (passage of urine at night)
Urine Dilution Test

(i) Bladder is Emptied.

(ii) 1,000 to 1,200 ml of water is given to the patient.

(iii) Urine sample is collected every hour for the next 4 hours.

(iv) Specific gravity is measured

(v) If the functioning of renal tubule is normal, the urinary specific gravity should fall to 1.005 or less.

(vi) If the renal tubules are diseased, the concentration of the solutes in urine will remain constant irrespective of excess water intake.
Acid Load Test

(i) Acid load test is used for the diagnosis of renal tubular acidosis.

(ii) Ammonium chloride is administered orally in a gelatin capsule (0.1g/kg body wt)

(iii) Ammonium chloride Dissociates into:
      \[ \text{NH}_4^+ \quad \text{Cl}^- \]
      (liver) ↓ ↓ (counted balanced by H+)
      urea Hcl
      ↓
      urine acidification

(iv) Urine is collected 2 – 8 hours after ingestion

(v) PH below 5.5 : Normal
    Between 5.5 to 7.0 : Renal tubular acidosis
Phenolsulfophthalein Test

(i)  Non – toxic dye
(ii) Excreted by kidneys
(iii) Intravenous injection of 6mg of PSP in /ml of saline is given.
(iv) Urine specimen collected at 15,30,60 and 120 minutes
(v) Rate of excretion of the dye is measured.
(iv) 15 minutes urine : 25% PSP  
1st hour urine : 40 – 60 5 PSP  
2nd hour urine : 20 to 25% PSP
(vii) Excretion less than 23% in 15 minutes urine sample indicates impaired Renal excretory function.
Renal Failure – Disorders

Failure of excretory functions of kidney
• ↓se GFR

ACUTE RENAL FAILURE

CAUSES:
(i) Acute Nephritis
(ii) Acute Tubular Necrosis
(iii) Renal calculi
(iv) Damage of Renal tissue

Features
(i) Oliguria
(ii) Anuria
(iii) Proteinuria
(iv) Hematuria
(v) Edema
(vi) Acidosis

CHRONIC RENAL FAILURE

CAUSES:
(i) Chronic Nephritis
(ii) Polycystic kidney
(iii) Renal calculi
(iv) Urethral constriction

Features
(i) Uremia
(ii) Acidosis
(iii) Edema
(iv) Anemia
(v) Hyperparathyroidism