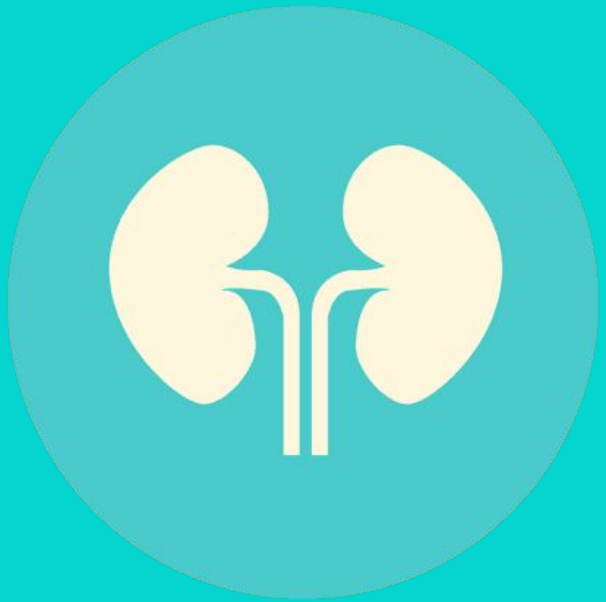
Renal Function Tests



Editing file

Objectives:

- Know the physiological functions of the kidney.
- Describe the structure and function of the nephron.
- Identify the biochemical kidney function tests with special emphasis on when to ask for the test, the indications and limitations of each kidney function tests.
- Interpret the kidney function tests properly.

Contents:

- Functional units
- Kidney functions
- Routine kidney function tests (KFTs):
  - Serum creatinine
  - Creatinine clearance
  - Cockcroft-Gault formula for GFR estimation
  - Serum Urea

Color Index:

- Important
- Dr's notes

Review

From females' doctor

Kidney function tests :

- Serum creatinine
- Creatinine clearance
- GFR estimation
- Serum Urea

Serum creatinine is the ideal test

➔ because it"s

- Constant
- Endogenous
- Freely filtered
- Not reabsorbed but 10% secreted

Creatinine clearance (GFR) = $\frac{U \times V}{P}$

➔ Normal range

- **Adults**: 110 ml/min
- **Elderly**: 70 ml/min

➔ Limitations

Urine collection

Why do we use Creatinine clearance?

- Indication of early impairment
- Monitor toxicity
- Follow up
- Renal transplant

Urea is the inferior test in KFT

➔ why?

- Affected by diet
- Affected by any disease that increase catabolism
- 50 % of urea filtered will be reabsorbed from the tubules.

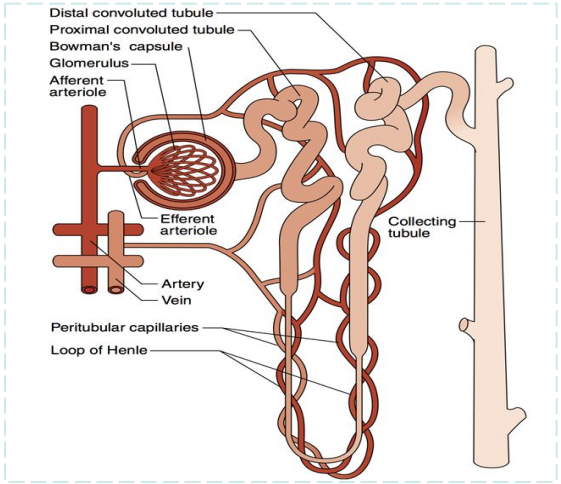
Cockcroft-Gault limitations:

- Body weight
- vegetarian people
- Low muscle mass

Functional units of kidney:

The nephron

- **Prevalence** — Each kidney contain 1,000,000 to 1,300,000 nephrons
- **Composition**
  - glomerulus — Ultra filtration
  - Renal tubules — Secretion; Reabsorption
- **Function** — Homeostasis



Representation of a nephron and its blood supply

☆Kidney functions :

1 Regulation

- Water and electrolyte balance.
- Acid base balance.
- Arterial blood pressure.[1]

2 Excretion

- Metabolic waste products
- Foreign chemicals.

3 Hormonal

- Secretion of erythropoietin
- Activation of vitamin D
- Activation of angiotensinogen → by renin

4 Metabolic

Gluconeogenesis

In males slides only

Nephron

☆ a complex apparatus comprised of **five** basic parts:

1 Glomerulus: filter incoming blood

Factors facilitate filtration

- **high pressure** "in the glomerular capillaries"
  - → Due to the position between two arterioles.
- **Semipermeability** "of the glomerular basement membrane"
  - has a molecular size cutoff value of approximately 66,000 Da.

2 Proximal convoluted tubule (PCT)

a. Returns valuable substances back to the circulation.

75% of:
- Water
- Sodium
- chloride.

Almost 100% of:
- Amino acids
- vitamins
- Proteins

100% of:
- Glucose (up to the renal threshold) *

Varying amounts of:
- Urea
- Uric acid
- Ions:
  - ☆ Magnesium ☆ Calcium ☆ Potassium.

b. Secretes products of kidney tubular cell metabolism

- Hydrogen ions
- Drugs "such as penicillin"

3 Loop of Henle

Facilitate reabsorption of:
- Water
- Sodium
- chloride.

Osmolality in medulla in this portion of nephron increases steadily from the corticomedullary junction inward.

4 Distal convoluted tubule (DCT)

- The filtrate entering this section of the nephron is close to its final composition.
- Effects small adjustments to achieve electrolyte and acid-base homeostasis (under the hormonal control of both antidiuretic hormone (ADH) and aldosterone)

DCT is shorter than PCT, with 2 or 3 coils that connect to a collecting duct.

Transported Passively "doesn't require energy"
The rest are transported actively "require energy"

Extra info :

* **Renal threshold:** the concentration of a substance dissolved in the blood above which the kidneys begin to remove it into the urine

Renal threshold for glucose: 180 mg/dL

When the renal threshold of a substance is exceeded, reabsorption of the Substance by the proximal Convoluted tubule is incomplete

In males slides only

Nephron

☆ a complex apparatus comprised of **five** basic parts:

5 Collecting duct

a. **The final site for concentrating or diluting urine.**

➔ **How it's achieved?**
Reabsorption of water and sodium Controlled by ADH and aldosterone

b. **Chloride and urea are also reabsorbed here.**

Kidney Function test

Why to test the renal functions?

Many diseases affect renal function.

In most diseases
destruction of complete nephron.
"several functions are affected"

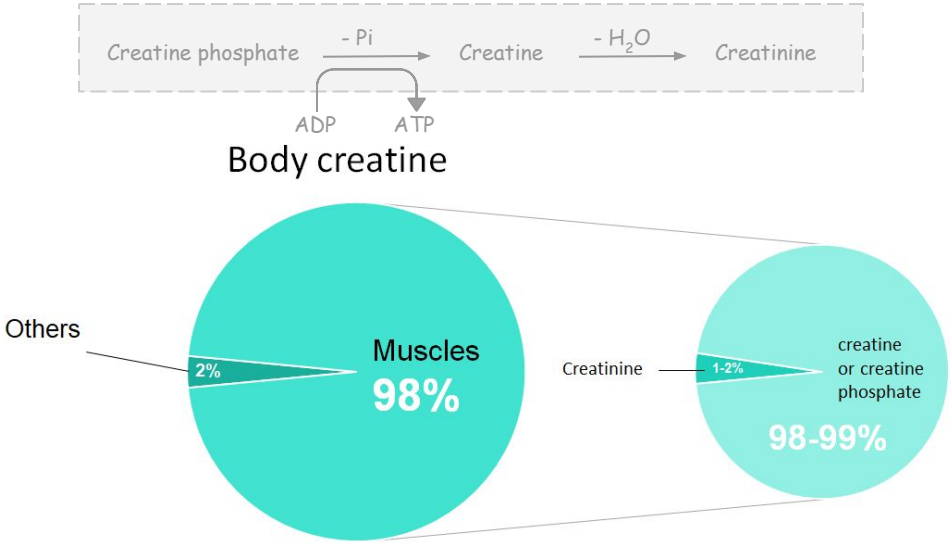
In others
Selective impairment of glomerular function or one or more of tubular functions.

Measurements:

- Serum creatinine (Cr).
- Creatinine clearance.
- Serum urea.
- Electrolytes

Serum creatinine

- Creatinine is the end product of creatine catabolism.
- 98% of the body creatine is present in the muscles where it functions as store of high energy in the form of creatine phosphate.
- About 1-2% of total muscle creatine or creatine phosphate pool is converted daily to creatinine through the spontaneous , non enzymatic* loss of water or phosphate.



Dr's note :

* This makes creatinine in kidney tests highly specific as there are no enzymes that can be defected or regulated.

It's levels depend only on renal clearance

Glomerular filtration rate (GFR)

☆ The volume of blood filtered per minute.

provides a useful index of the number of **functioning** glomeruli

Gives an estimation of the **degree** of renal impairment by disease

Criteria of substances used in clearance tests that accurately measure GRF:

☆ requires determination of the concentration in plasma and urine

Criteria	Creatinine
Freely filtered at glomeruli	✓
Not reabsorbed by renal tubules	✓
Not secreted by renal tubules	**10%** of urinary creatinine is secreted
Constant concentration in plasma throughout urine collection.	✓ remains constant throughout adult life.
Present endogenously. (not affected by diet) * Better	✓
Easily measured.	✓

Creatinine clearance

☆ Clearance : The volume of plasma cleared from the substance excreted in urine per minute.

$$\text{Clearance (ml/min)} = \frac{U \times V}{P}$$

U: concentration of creatinine in urine (µmol/L)

V: volume of urine per min [1]

P: concentration of creatinine in plasma (µmol/L)

20-40 years adults

usually about 110 ml/min

Over 80 years & females

falls slowly but progressively to about 70 ml/min [2]

children

the GFR should be related to surface area, when this is done, results are similar to those found in young adults.

Dr's notes :

1. Urine is collected through 24h period then it's mathematically converted to amount per minute

2. due to decrease in muscle mass

Cockcroft-Gault Formula

An alternative and convenient method that employ a formula devised to calculate creatinine clearance using parameters such as:

- **Serum creatinine level**
- **Sex**
- **Weight of the subject.**

$$GFR = \frac{K \quad (140\text{-age}) \times \text{Body weight}}{\text{Serum creatinine } (\mu mol/L)}$$

K: a constant that varies with sex

1.23 for males

1.04 for females.

it's used as females have a relatively lower muscle mass.

It should not be used if:

1. Serum creatinine is changing rapidly *
2. unusual diet
   e.g. strict vegetarian
3. Low muscle mass
   e.g. muscle wasting
4. Obesity

Dr's notes :

* For example in athlete (body building) ppeople as the muscle mass is changing.

Serum creatinine is A Better KFT Than creatinine clearance because :

1. Serum creatinine is more accurate because creatinine clearance is measured by using a 24-hour urine collection

this does introduce the potential for errors in terms of completion of the collection [1]

2. Serum creatinine level is constant throughout adult life

Creatinine Clearance Is Only Recommended In The Following Conditions :

- Patients with early (minor) renal disease.
- Assessment of possible kidney donors.
- Detection of renal toxicity of some nephrotoxic drugs.

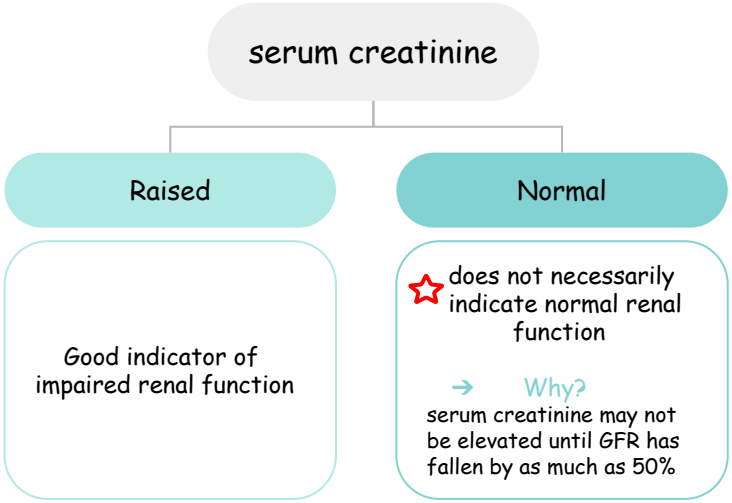
Both serum creatinine and creatinine clearance are used as kidney function tests to :

- Confirm the diagnosis of renal disease.
- Give an idea about the severity of the disease.
- Follow up the treatment.

Normal Adult Reference Values

Urinary excretion of creatinine is 0.5 - 2.0 g per 24 hours in a normal adult, varying according to muscular weight.

Serum creatinine	55 – 120 µmol/L
Creatinine clearance	Males: 90 – 140 ml/min Females: 80 – 125 ml/min

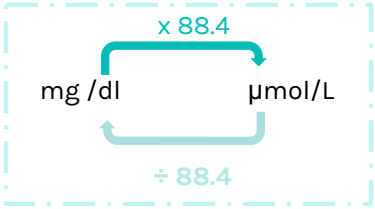


In females slides only

How To Convert Creatinine Concentration From mg/dl to µmol/L?

THE CONVERSION FACTOR IS (88.4)

1 mg/dl = 88.4 µmol/l



* was added by females' doctor

Serum Urea

Urea is formed in the liver from ammonia released from deamination of amino acid. (Urea cycle)

Normal range (2.5-6.6 mmol/L) in adult

As a kidney function test, serum urea is inferior to serum creatinine because:

1. High protein diet increases urea formation
2. Any condition of increased proteins catabolism will increase urea formation.
   - Cushing syndrome
   - Thyrotoxicosis
   - diabetes mellitus
   - Starvation
3. **50%** or more of urea filtered at the glomerulus is passively reabsorbed by the renal tubules
4. Dehydration can increase urea *

Normal Values Of Internal Chemical Environment Controlled By The Kidneys	
SODIUM	135 - 145 mEq/L
POTASSIUM	3.5 - 5.5 mEq/L
CHLORIDES	100 - 110 mEq/L
BICARBONATE	24 - 26 mEq/L
CALCIUM	8.6 - 10 mg/dl
MAGNESIUM	1.6 - 2.4 mg/dl
PHOSPHORUS	3.0 - 5.0 mg/dl
URIC ACID	2.5 - 6.0 mg/dl
pH	7.4
CREATININE	0.8 - 1.4 mg/dl
BUN (Blood Urea Nitrogen)	15 - 20 mg/dl

Dr's note :

You don't have to memorize the values

Quiz

MCQs :

Q1: One of the hormonal functions of kidney
a) Electrolyte balance **b)** Secrete erythropoietin **c)** Excretion of waste products **d)** Gluconeogenesis

Q2: Urea formation is increased with
a) Diet without meat **b)** High carbohydrate diet **c)** Protein anabolism **d)** Cushing syndrome

Q3: creatinine clearance in people over 80 years old is
a) 110 ml/min **b)** 70 ml/min **c)** 90 ml/min **d)** 40 ml/min

Q4: K constant for males is
a) 1.23 **b)** 1.74 **c)** 1.04 **d)** 1.32

Q5: Cockcroft-gault formula should not be used when
a) Serum creatinine is constant **b)** Muscle mass is normal **c)** The diet is unusual **d)** BMI is normal

Q6: Normal range of serum urea in adult is
a) 2.5-7.7 mmol/L **b)** 3.6-6.6 mmol/L **c)** 3.6-8.8 mmol/L **d)** 2.5-6.6 mmol/L

Q7: To measure glomerular filtration you need a substance that is
a) Has a limited filtration **b)** Exogenous **c)** Endogenous **d)** Reabsorbed by renal tubules

Q8: Creatinine clearance is best used for
a) Glomerulonephritis **b)** Renal failure **c)** Minor renal impairment **d)** Cystitis

SAQs :

Q1: what are the kidney functions?

Q2: why do we use creatinine in creatinine clearance test?

Q3: why serum urea is inferior to serum creatinine?

Q4: 77 year-old male patient came to the clinic with sudden lower back pain, a serum creatinine analysis was done and the serum creatinine level was 0.55mg/dL, calculate the glomerular filtration rate knowing that the patient's body weight is 63kg.

★ MCQs Answer key:

1) B 2) D 3) B 4) A 5) C 6) D 7) C 8) C

★ SAQs Answer key:

1) Regulation - Excretion - Hormonal Function - Metabolic Function

2) because its Freely filtered at glomeruli and easily measured

3) High protein diet increases urea formation,Any condition of increased proteins catabolism will increase urea formation,, 50% or more of urea filtered at the glomerulus is passively reabsorbed by the renal tubules.

4) GFR = (K * (140-age) * body weight) / serum creatinine µmol/L
To convert mg/dL to µmol/L we need to multiply by 88.4
Serum creatinine = 0.55 * 88.4 = 48.62µmol/L
GFR = (1.23 * 63 * 63)/48.62µmol/L
GFR=100.408 mL/min

☆ Don’t study because you need to, study because knowledge is power and they can never take it away from you.

We hear you

☆ Team members :

Girls team:

- Ajeed Al-rashoud
- ★ Alwateen Albalawi
- Abeer Alkhodair
- Elaf Almusahel
- Haifa Alessa
- Lama Alassiri
- Lina Alosaimi
- Nouf Alhumaidhi
- Noura Alturki
- Nouran Arnous
- ★ Reem Algarni
- Rema Alkahtani
- ★ Shahd Alsalamh
- Taif Alotaibi

Boys team:

- Alkassem binobaid
- Fahad Alsultan
- Fares Aldokhayel
- Naif Alsolais
- Sultan Alhammad

☆ Team leaders :

Deema Almaziad

Mohannad Alqarni