Renal failure / د. شذى كاظم عطره / م. رابعة 2023-2024

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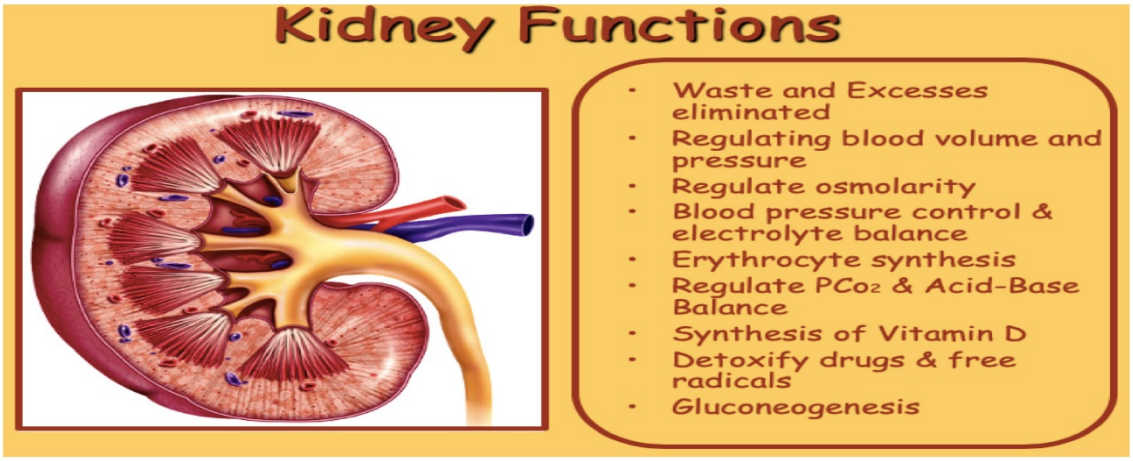
Education & definition:

The renal system **consists** of the *kidney, *ureters, and *the urethra.
The overall function of the system **filters** approximately 200 liters of fluid a day **from** renal blood flow
Which **allows** for *toxins, *metabolic waste products, and *excess ion to be **excreted** while **keeping** essential substances in the blood.

What are the main functions of the kidney?



The 7 functions of the kidneys

- A - Controlling ACID-base balance.
- W - Controlling WATER balance.
- E - Maintaining ELECTROLYTE balance.
- T - Removing TOXINS and waste products from the body.
- B - Controlling BLOOD PRESSURE.
- E - Producing the hormone ERYTHROPOIETIN.
- D - Activating vitamin D.

The function of the renal system, as **it** **relates** to the practice of **anesthesia** in the **perioperative period**, **involves**:
1) systemic removal and excretion of anesthetic medications,
2) regulating hemoglobin levels, as well as
3) maintaining acid-base and fluid balance.

How does anesthesia affect the urinary system?
The **anesthetic agents** **:**

a. **decrease** the intra-bladder pressure and
b. inhibit the micturition reflex.

Halothane **decreases** *bladder contractions and **increases** *its capacity measured by the cystometrogram.
Urinary retention is a **side effect of opioids**, particularly after **intra-thecal**

The effect of anaesthesia on renal function

Anaesthesia and **surgical stress** can affect renal function and body fluid regulation ***indirectly** as well as ***directly**. **The indirect effects,** through:

a) It **influences** on *haemodynamics, *sympathetic activity and *humoral regulationالتنظيم الخلطي , are more pronounced than the **direct** ones.

b) **Inhalational anaesthetics** generally **reduce** *glomerular filtration rate and *urine output, **mainly** by extra-renal effects that are **attenuated**مخفف by pre-operative hydration.
c) **Opioids, barbiturates and benzodiazepines** also **reduce** *glomerular filtration rate and *urine output.
d) The effects of **regional anaesthesia** seem to be less than those of general anaesthesia and are related to changes in systemic hemodynamics.
These **peri-operative**المحيطة بالجراحة **alterations** of renal function are usually transient and clinically insignificant.
e) **Mechanical ventilation** **decreases** urine volume and sodium excretion **to an extent** that depends on the increase in intrathoracic pressure, **though** **ADH release**, **unloading**التفريغ of **baroreceptors** and **activation** of the **renin-angiotensin system** may also be involved.

The direct effects of anaesthesia **which** are dose- and agent-dependent **include**:
a) Effects on autoregulation of **renal blood flow**,
b) Alteration in the effect of **ADH**, and
c) Effects on **tubular transport** of *sodium and *organic acids.

The only proven **direct toxic effect** of any anaesthetic agent **is the** fluoride-related toxicity of methoxyflurane.

The term renal failure **denotes** inability of the kidneys to perform excretory function **leading** to retention of nitrogenous waste products from the blood.

Acute and chronic renal failure are the **two** kinds of kidney failure.

When a patient **needs** "renal replacement therapy", **the condition is called** **end-stage renal disease (ESRD)**.

The causes, pathophysiology, presentation and diagnosis of renal failure and highlights **the role of the 'interprofessional team"** in its **management**.

Objectives of the lecture:

- Recall the causes of renal failure.
- Describe the laboratory features of renal failure.
- Summarize the treatment options for renal failure.
- Explore modalities to improve care coordination among "interprofessional team" **members** in order to improve outcomes for patients affected by renal failure.

Introduction

Functions of the kidney are as **follows**:

1. Electrolyte and volume regulation
2. Excretion of nitrogenous waste
3. Elimination of exogenous molecules, for example, many **drugs**
4. Synthesis of a variety of hormones, for example, **erythropoietin**
5. **Metabolism** of low molecular weight proteins, for example, **insulin**

Acute and **chronic** renal failure are the **two** kinds of kidney failure.

Acute Renal Failure (ARF)

ARF is the syndrome in which glomerular filtration declines **abruptly** (**hours to days**) and is **usually** **reversible**.
According to the KDIGO criteria in 2012, **AKI** can be diagnosed with any one of the following:
(1) the creatinine increase of 0.3 mg/dl **in 48 hours**,
(2) the creatinine increase to 1.5 times baseline within **last 7 days**, or
(3) the urine volume less than 0.5 mL/kg per hour for 6 hours.

Recently the term "acute kidney injury" (AKI) has replaced ARF because AKI denotes the entire clinical spectrum from a mild increase in serum creatinine to overt renal failure.

Chronic Renal Failure (CRF)

CRF or chronic kidney disease (CKD) is defined as a persistent impairment of kidney function, in other words, abnormally elevated serum creatinine for more than 3 months or calculated glomerular filtration rate (GFR) less than 60 ml per minute / 1.73m2.

It often **involves** a progressive loss of kidney function **necessitating** renal replacement **therapy** (**dialysis** or **transplantation**).

When a patient needs renal replacement therapy, the **condition** is called **end-stage renal disease** (**ESRD**).

CKD classified

CKD classified based on grade:

1. Grade 1: **GFR** greater than 90

2. Grade 2: **GFR** 60 to 89
3. Stage 3:
    a. Grade 3a: **GFR** 45 to 59
    b. Grade 3b: **GFR** 30 to 44
4. Grade 4: **GFR** 15 to 29
5. Grade 5: **GFR** Less than 15

Etiology: Renal Failure Etiopathogenesis

Acute Renal Failure

Prerenal (approximately 60%):

a. ***hypotension**,
b. ***volume** contraction (e.g., sepsis, hemorrhage),
c. *severe **organ** failure such as heart failure or liver failure,
d. ***drugs** like non-steroidal anti-inflammatory drugs (NSAIDs), angiotensin receptor blockers (ARB) and angiotensin-converting enzyme inhibitors (ACEI), and cyclosporine

Intrarenal (approximately 35%):

a. Acute tubule necrosis (from prolonged prerenal failure,
b. Radiographic contrast material,
c. Drugs like aminoglycosides, or nephrotoxic substances),
d. Acute interstitial nephritis (drug-induced),
e. Connective tissue disorders (vasculitis),
f. Arteriolar insults,
g. Fat emboli,
h. Intrarenal deposition (seen in tumor-lysis syndrome, increased uric acid production and multiple myeloma-bence-jones proteins),
i. Rhabdomyolysis

Postrenal (approximately 5%): Extrinsic compression (prostatic hypertrophy, carcinoma), intrinsic obstruction (calculus, tumor, clot, stricture), decreased function (neurogenic bladder)

Chronic Renal Failure:

1. Diabetes mellitus, especially type 2 diabetes mellitus, is the most frequent cause of ESRD.
2. Hypertension is the second most frequent cause.
3. Glomerulonephritis
4. Polycystic kidney diseases
5. Renal vascular diseases
6. Other known causes, like prolonged obstruction of the urinary tract, nephrolithiasis
7. Vesicoureteral reflux, a condition in which urine to back up into the kidneys
8. Recurrent kidney infections/ pyelonephritis
9. Unknown etiology

Epidemiology

The **incidence** of ARI has been cited as 1% on hospital admission, 2% to 5% during hospitalization, and in as many as 37% of patients treated in intensive care units (ICUs), and in 4% to 15% of patients after cardiovascular surgery.

1. Overall, the incidence of AKI has been **estimated** to be **209** patients per **million** population per **year**, with **36%** of patients with **ARI requiring** renal replacement therapy.
2. The incidence and prevalence of CRF in the United States are uncertain. The third National Health and Nutrition Examination Survey (NHANES III) shows that almost 2 million people in the United States have a serum creatinine level of 2 mg/dl or greater.
3. **CRF** is **known** to be more prevalent in men than in women. This **gender** disparity extends to **ESRD.**
4. **ESRD develops** in **over 100,000 persons a year in** the United States.
5. **Rates of ESRD vary** with **race**. Both the ***incidence** and ***prevalence** of **ESRD** are three to four **times** higher in **blacks** than in **whites**.

What are the symptoms of kidney failure?

Symptoms of acute kidney failure

Signs and symptoms of acute kidney failure can include:

1. decreased amount of **urine** (weeبول)

2. **oedema** (fluid or water retention — most commonly swollen ankles)
3. **confusion**
4. **nausea**
5. feeling **breathless**

Symptoms of chronic kidney disease

Signs and symptoms of chronic kidney disease may include:

1. **hypertension** (high blood pressure)
2. **night-time urination** (weeing)
3. changes in how your **urine looks** (such as frothy or foamy)
4. **haematuria** (blood in your urine)
5. **oedema** or **puffiness** (in the legs, ankles or around the eyes)
6. **tiredness** or **weakness**
7. **nausea** (feeling sick) or vomiting
8. **itching**
9. **restless legs**
10. **breathlessness**

If you notice any of these symptoms, see your doctor.

Pathophysiology

Renal failure pathophysiology can be **described** by a sequence of events that **happen** while during **acute** insult in the setting of acute renal failure and also **gradually** over a period in cases of chronic kidney diseases.
Broadly, **AKI** can be classified into **three** groups:

1. **The decrease in renal blood flow** (**prerenal azotemia**): **Azotemia** is a biochemical abnormality, defined as elevation, or buildup of, **nitrogenous** products (***BUN**-usually ranging 7 to 21 mg/dL), ***creatinine** in the **blood**, and other **secondary waste products** within the body. **Prerenal AKI** occurs **secondary** to either an absolute **reduction** in "extracellular fluid volume" or a reduction in "circulating volume" despite a normal total fluid volume, e.g., in advanced cirrhosis, heart failure, and sepsis.
   Normally kidney auto-regulatory mechanism **maintains** "intra-capillary pressure" during **initial phase** by **causing** dilation of afferent arterioles and constriction of efferent arterioles.
   When prerenal conditions become **severe**, renal adaptive mechanisms **fail** to compensate unmasking the fall in GFR and the increase in BUN and creatinine levels.
2. **Intrinsic renal parenchymal diseases** (renal azotemia): Intrinsic disorders can be sub-divided into those involving the ***glomeruli**, ***vasculature**, or ***tubulointerstitium** respectively.
3. **Obstruction of urine outflow** (postrenal azotemia)

The pathophysiology of CRF is **related** mainly to specific initiating mechanisms. Over the course of **time-adaptive physiology plays** a role leading to compensatory hyperfiltration and hypertrophy of remaining viable nephrons.
As insult continues, sub sequentially histopathologic changes occur which **include** distortion of glomerular architecture, abnormal podocyte function, and disruption of filtration **leading** to **sclerosis**.

History and Physical

The relevant history and physical examination findings associated with renal failure include:

History

1. Detailed present medical illness history
2. Medical history such as diabetes mellitus, hypertension
3. A family history of kidney diseases
4. Review of hospital records
5. Previous renal function
6. Medications especially start date, drug levels of nephrotoxic agents, NSAIDs
7. Any use of a contrast agent or any procedure performed

Physical examination

1. Hemodynamics including blood pressure, heart rate, weight
2. Volume status, look for edema, jugular venous distention, lung crackles, and S3 gallop
3. Skin: check for any diffuse rash or uremic frost

4. Look for signs of uremia: asterixis, lethargy, seizures, pericardial friction rub, peripheral neuropathies
5. Abdomen exam: check for bladder distention, note any suprapubic fullness

Evaluation

Patients with **renal failure** have a **variety of different clinical presentations** as explained in the **history and physical exam section.**

Many patients are asymptomatic and are **incidentally** found to have *an elevated serum **creatinine** concentration, **abnormal **urine** studies (such as ***proteinuria** or microscopic ***hematuria**), or ***abnormal radiologic imaging of the **kidneys**.

The key *laboratory and *imaging studies to be **ordered** in patients with **"renal failure"** **follow**.

Laboratory Tests

- **Urinalysis**, dipstick, and microscopy

1. Dipstick for **blood** and **protein**; microscopy for *cells, *casts, and *crystals
2. **Casts**: Pigmented granular/muddy brown casts- acute tubular nicrosis(ATN); WBC casts-acute interstitial nephritis; RBC casts-glomerulonephritis

- **Urine electrolytes**

Fractional excretion of sodium (FENa) = [(UNa x PCr)/ (PNa x UCr)] x 100, where U is urine, P is plasma, Na is sodium, and Cr is Creatinine.

If FeNa **less** than 1, then likely prerenal; **greater** than 2, then likely intrarenal; **greater** than 4, then likely postrenal

If the patient is on **diuretics**, use FEurea instead of FENa. Complete blood count, BUN, creatinine (Cr), arterial blood gases (ABGs)

- **Calculate Cr clearance** to ensure that medications are dosed appropriately: Cockcroft-Gault equation Cr clearance (mL/min) = (140-age) x (weight in kilograms) x (0.85 if female)/(72 x serum creatinine)

Special Labs

- **Creatinine Kinase** (CK)
- **Immunology antibodies** based on the clinical scenario

Imaging

- Renal ultrasound (US)
- Doppler-flow kidney US depending upon the clinical scenario
- An abdominal x-ray (KUB): Rules out renal calculi

More advanced imaging **techniques** should be considered if initial tests do not reveal etiology:

- Radionucleotide renal scan, CT scan, and/or MRI
- Cystoscopy with retrograde pyelogram
- Kidney biopsy

Treatment / Management

Treatment **options** for renal failure **vary widely** and depend on the cause of failure. Broadly options are **divided** into **two groups**:

1) **treating** the **cause** of **renal failure** in acute states
2) versus replacing the renal function in **acute** or **chronic** **situations** and chronic **conditions**.

Below is the summary of renal failure treatment.

Acute Renal Failure treatment:

1. Mainstay is treating the **underlying cause** and associated **complications**
2. In case of **oliguria** and **no volume**, overload is noted, a fluid challenge may be appropriate with "diligent monitoring"المراقبة الدقيقة for **volume overload**
3. In the case of **hyperkalemia** with ECG changes, **IV calcium**, **sodium bicarbonate**, and **glucose with insulin** should be **given**. These measures drive potassium into cells and can be **supplemented** with polystyrene sulfonate, **which removes** *potassium from the body. **Polystyrene sulfonates** are a group of medications used to treat high blood potassium. Effects generally take hours to days. They are also used to remove potassium, calcium, and sodium from solutions in technical applications.
4. **Hemodialysis** is also an emergency method of removal.
5. **Oliguric** patients should have a fluid restriction of 400 mL + the previous day's urine output (unless there are signs of volume depletion or overload).

6. If **acidosis**: Serum bicarbonate intravenous or per oral, versus emergency/urgent dialysis based on the clinical situation
7. If **obstructive** etiology present treat accordingly and or if bladder outlet obstruction secondary to prostatic hypertrophy may benefit from Flomax or other selective alpha-blockers

General Measures

1. First things first, always review the drug list.
2. Stop nephrotoxic drugs and renally adjust others. Many supplements not approved by the FDA can be nephrotoxic.
3. Always record ins and outs
4. Monitor daily weights
5. Watch for complications, including hyperkalemia, pulmonary edema, and acidosis-all potential reasons to start dialysis
6. Ensure good cardiac output and subsequent renal blood flow.
7. Pay attention to diet: total caloric intake should be 35 to 50 kcal/kg per day to avoid catabolism. Potassium intake restricted to 40 mEq per day; phosphorus restricted to 800 mg per day. If it becomes high, treat with "calcium carbonate" or other phosphate binder. Magnesium compounds should be avoided.
8. Treat infections aggressively.

Immediate Dialysis Indications

1. **Severe hyperkalemia**
2. **Acidosis**
3. **Volume overload refractory to conservative therapy**
4. **Uremic pericarditis**
5. **Encephalopathy**
6. **Alcohol and drug intoxications.**

Chronic Renal Failure

1. Optimize **control** of specific **causes** of CKD such as diabetes mellitus and hypertension
2. Measure sequentially and plot the rate of decline in GFR in all patients
3. Any acceleration in the rate of decline should prompt a search for superimposed acute or subacute process that may be reversible
4. Rule out extracellular fluid volume depletion, uncontrolled hypertension, urinary tract infection, new obstructive uropathy, exposure to nephrotoxic agents (such as NSAIDs or contrast dye), reactivation or flare of the original disease such as lupus or vasculitis
5. Interventions to slow the progression of CKD
6. Reduce intra-glomerular **filtration**
7. Reduce proteinuria; effective meds include ACE/ARB
8. Strict glycemic control
9. Prevent and treat complications of CKD
10. Discuss renal replacement therapy with patients appropriately and timely
11. Periodically review medications and avoid nephrotoxic medicines. Dose renally excreted medications appropriately.
12. Patients with CKD should be referred to a nephrologist when eGFR is less than 30 ml per minute, as this provides enough time for adequate preparation for kidney replacement therapy.

Differential Diagnosis

- Acute kidney injury
- Alport Syndrome
- Antiglomerular Basement membrane disease
- chronic glomerulonephritis
- Diabetic neuropathy
- Multiple Myeloma
- Nephrolithiasis
- Nephrosclerosis

Complications

1. **Volume overload**
2. **Hyponatremia**

3. **Hyperkalemia**
4. **Acidosis**
5. **Calcium and phosphate balance**
6. **Anemia**

Consultations

1. Consult **nephrology** in all cases where the patient has a drop in urine output with elevated creatinine.
2. Urology consultation for obstructive nephropathies
3. Relief of obstruction with retrograde ureteral catheters or percutaneous nephrostomy
4. **Surgical** consults for placement of hemodialysis catheter

Pearls and Other Issues

1. **Fractional excretion of sodium (FENa)** is not a test. Instead it is a calculation based on the **concentrations** of **sodium** and **creatinine** in the blood and urine. The typical "FeNa values" for each type of AKI: Pre-renal: Less than 1%; Intrinsic renal greater than 2%; Post-renal: Greater than 4%. A value of the FENa below 1% commonly indicates prerenal disease; in comparison, a value between 1% and 2% may be seen with either disorders, and a value above 2% usually indicates ATN. **What is a normal FENa value?**

The FENa is a **measure** of the *extraction of sodium and water from the glomerular filtrate. It is the **ratio** of the sodium filtration rate to the overall glomerular filtration rate (GFR).

An euvolemic person with normal renal function and moderate salt intake in a steady state will have FENa approximately 1%.

2. **The typical BUN/creatinine ratios** for each type of AKI: Pre-renal greater than 20:1; Intrinsic renal Less than 10:1; Post-renal or normal 10 to 20:1.
3. **Patients who get diuretics** may have a **higher** urinary concentration of **sodium**" due to the diuretic, falsely elevating the fractional excretion of sodium. In these patients, use the fractional excretion of urea (FeUrea) instead since it is relatively unaffected by diuretics.
4. **Serum creatinine** used as a **marker** of kidney function is affected by muscle mass (lower muscle mass = falsely low serum creatinine).
5. **The Modification of Diet in Renal Disease (MDRD) formula** includes *age, *gender, *race, *BUN, *creatinine, and *albumin. These are all important **factors** in measuring kidney function (GFR) and all automatically printed in lab reports.
6. Prevention of AKI **begins** before hospitalization by obtaining a nephrology consultation appropriately in patients with CKD 3, CKD 4, and CKD 5
7. **Adjust doses of medications** according to estimated glomerular filtration rate (GFR)
8. **Watch for hyperkalemia** while taking simultaneous ACEI or ARB/spironolactone in patients with CKD
9. Check for **bone mineral disorders** in patients with CKD

Enhancing Healthcare Team Outcomes

The management of kidney failure is usually done with an interprofessional team of healthcare professionals dedicated to preserving renal function. Kidney failure has enormous morbidity and mortality, costing the healthcare system billions of dollars each year. Today most hospitals have a kidney failure nurse whose job is to educate patients on the causes, detection, and prevention of kidney failure. The pharmacist also needs to regularly audit patient medications for those that are nephrotoxic. When monitoring patients with kidney failure, the nurse should note the urine output, levels of potassium, blood sugar and creatinine. Control of blood pressure and blood sugars is vital in the prevention of kidney disease. The diabetic nurse should closely monitor the renal function of all diabetics and refer patients to the nephrologist if the renal function is deteriorating. The pharmacist should emphasize the importance of medication compliance for treatment of blood pressure. These patients should have close follow up to ensure that the renal function is not deteriorating. Finally, the patient needs to be given advice on healthy eating, exercise, discontinuing tobacco and abstaining from alcohol. Kidney disease is not well managed can lead to complete renal failure, which requires dialysis.[11][12] (level V) Only through open communication between the team members can the morbidity and mortality of renal failure be lowered.

Outcomes

Recovery from acute renal failure depends on the cause of the disease. If the cause is reversible, the prognosis is good and leans toward a full recovery. Partial recovery of renal function may occur if the injury does not fully resolve. Severe cases of acute renal failure can result in death.

1. The prognosis for hospitalized patients with AKI **depends** largely on the site (ICU or floor).
2. The mortality rate of patients with AKI on a ventilator is **about 80%.**
3. **AKI** patients are at increased risk for progressing into **CKD** during their lifetime.

4. **CKD** is correlated with high morbidity and mortality. *Cardiovascular mortality is 10 to 30 times higher in **ESRD patients** treated with dialysis compared to those in **the general population**. (Level V)

Quiz:

What is the definition of renal failure?

The term renal failure denotes inability of the kidneys to perform excretory function **leading** to retention of nitrogenous waste products from the blood.
Acute and **chronic renal failure** are the **two** **kinds** **of kidney failure**.

What are 2 types of renal failure?

There are two different types of kidney failure - acute and chronic.

1. Acute kidney failure has an abrupt onset and is potentially reversible.
2. Chronic kidney failure progresses slowly over at least three months and can lead to permanent kidney failure.

Types of Kidney Failure - Stanford Health Care
stanfordhealthcare.org
https://stanfordhealthcare.org › medical-conditions › types

What are the 5 stages of kidney failure?

Use the links below to learn about each stage of kidney disease:

1. Stage 1 with normal or high GFR (GFR > 90 mL/min)
2. Stage 2 Mild CKD (GFR = 60-89 mL/min)
3. Stage 3:
    a. Stage 3A Moderate CKD (GFR = 45-59 mL/min)
    b. Stage 3B Moderate CKD (GFR = 30-44 mL/min)
4. Stage 4 Severe CKD (GFR = 15-29 mL/min)
5. Stage 5 End Stage CKD (GFR <15 mL/min)

Stages of Chronic Kidney Disease - DaVita
davita.com
https://www.davita.com › education › stages

What is the first indication of kidney failure?

Kidney failure is a condition in which **one** or **both** of your kidneys no longer work on their own. **Causes** include *diabetes, *high blood pressure and *acute kidney injuries. **Symptoms** include *fatigue, *nausea and *vomiting, *swelling, *changes in how often you go to the bathroom and *brain fog.٠٤/١٠/٢٠٢٢

Kidney Failure: Causes, Symptoms & Treatment - Cleveland Clinic
clevelandclinic.org
https://my.clevelandclinic.org › health › diseases › 1768...

How do you diagnose kidney failure?

What tests do doctors use to diagnose and monitor kidney disease?

1. A **blood test** that checks how well your kidneys are filtering your blood, called GFR. GFR stands for glomerular filtration rate.
2. A **urine test** to check for albumin. Albumin is a protein that can pass into the urine when the kidneys are damaged.

What anesthetics are kidney friendly?

Short-acting anesthetic drugs are **recommended** (propofol, remifentanil, cisatracurium, vecuronium).
Sevoflurane can deteriorate renal function by fluoride ion and compound A production,
So **isoflurane** remains the preferred anesthetic **inhalator agent**.
Anesthetic Considerations for Patients with Chronic Kidney Disease

What is the anesthetic agent of choice in renal failure?

Of the **volatile anaesthetics** currently **available**, halothane is the **agent of choice**.

Anaesthesia for the patient with impaired renal function - PubMed
nih.gov
https://pubmed.ncbi.nlm.nih.gov › ...

What anesthesia is used for renal failure patients?

If possible the shorter acting sedative agents should be used.
If spinal or epidural anaesthesia is being performed fluid preloading **should be kept to a minimum** and vasoconstrictors **used to maintain the blood pressure**. Otherwise postoperative fluid overload may necessitate dialysis.
Anaesthesia and chronic renal failure - WFSA - Resources

Anesthetic Considerations for Patients with Chronic Kidney Disease:

Chronic kidney disease (CKD)

- It is defined as either: **a glomerular filtration rate (GFR) of <60 ml min^{-1}** 1.73 m^{-2} **for 3 months** or **more**, irrespective of **cause**,
  or kidney damage leading to a decrease in GFR, present for 3 months or more (1).

The damage may **manifest** as abnormalities in the composition of **blood** or **urine**, **on radiological imaging**, or **in histology**.

Classification of Chronic kidney disease (CKD)

CKD is classified into **five stages** **depending** on GFR, **ranging** from "Stage 1" (normal GFR) to "Stage 5" (established renal failure) (1).
According to the NIDDK, more than 30 million American adults may have CKD (2).
Safe anesthetic management **requires** an understanding of CKD pathophysiology **to prevent** aggravation **of pre-existing disease** (1).
Depending on *the patient's **status** and *the surgical **procedure**, the:

preoperative evaluation

- **preoperative evaluation** may **require** **close communication** between the *primary care physician, *nephrologist, *surgeon, and *anesthesiologist **to determine** **if** a patient is optimized for surgery.
- The **following** **assessments** are recommended for patients with CKD:
  i. Comorbid **conditions**,
  ii. **Severity** of CKD assessed by level of kidney function,
  iii. **Complications** related to level of kidney function,
  iv. **Risk** for loss of kidney function, and
  v. **Risk** for cardiovascular disease.

  The **risk** for cardiovascular complications should be promptly **evaluated**. The patient should undergo **a routine electrocardiogram**.
- **All present preoperative abnormalities**, such as ***anemia, *hyperkalemia, and *metabolic acidosis**, should be **preoperatively** **corrected**.
- **A hemoglobin value of 10 g/dl is strongly recommended** (4).
- **Calcium chloride**, **insulin** and **dextrose**, **sodium bicarbonate**, and **resins** can be used **to correct hyperkalemia.**
- **If the patient is under dialysis treatment**, the **final dialysis** **prior to surgery** **should be** scheduled 12-24 hours before surgery.

The anesthetic management of patients suffering from CKD

It is **complex**. Due to **delayed** gastric emptying and **neuropathy**, there is risk **of gastric acid aspiration**.

Gastric aspiration prophylaxis can be managed using: * sodium citrate, *metoclopramide, *anti-H2 drugs, and * "**rapid induction"**.

Short-acting anesthetic drugs are recommended (**propofol, remifentanil, cisatracurium, vecuronium).**
Sevoflurane can deteriorate renal function by "fluoride ion" and "compound A" **production**, **so** isoflurane remains the preferred anesthetic inhalator agent.

When selecting a neuromuscular blocking agent (NMBA) for use in patients with CKD, the anesthesiologist should **consider** the impact of renal impairment on **(a)** the elimination of the drug, **(b)** the potential for drug accumulation with incremental doses, and **(c)** the production of active metabolites.
To prevent postoperative residual curarization (PORC), long-acting NMBAs should be avoided (2).
Postoperative residual curarization (PORC) or **residual** neuromuscular blockade (RNMB) is a residual **paresis** after emergence from general anesthesia that may **occur** with the use of neuromuscular-blocking drugs.
Postoperative residual paralysis (PORP), also known as re- sidual postoperative neuromuscular blockade, is defined as postoperative **paralysis** or **muscle weakness** due to **incomplete** or **absent** antagonism of non-depolarizing neuromuscular **blockers** (NMB) 1(D).

Opioids may be used, as they **have no direct toxic effects on the kidney**. They do, have an antidiuretic effect, and they **may cause urinary retention**.
Lastly, patients with Stage 5 CKD who have undergone renal transplantation **require** immunosuppression. These **drugs** are usually given by the **oral route**. If **enteral administration** is inappropriate, then **IV administration** with dose adjustment will be required.

Postoperative management for CRD:

After surgery, postoperative pain management should **begin**. **Special emphasis** should be placed **on preventing** further deterioration of renal function **as well as protection** of existing renal function in patients with "**moderate" to "severe" impairment from** the **effects** of anesthetics and pain medications.
For example, **analgesics** such as "non-steroidal anti-inflammatory drugs" (NSAIDs) **can contribute** to a **reduction** of the residual renal function in CKD and should be avoided.
Further clinical studies are required to **address** the optimal medication regimen **that can be used** for **postoperative pain management** in the more **severe** stages of CKD, **including hemodialysis** (5).

References

1. R. G. Craig, J. M. Hunter, Recent developments in the perioperative management of adult patients with chronic kidney disease, *BJA: British Journal of Anaesthesia*, Volume 101, Issue 3, September 2008, Pages 296–310, https://doi.org/10.1093/bja/aen203
1. Centers for Disease Control and Prevention. National Chronic Kidney Disease Fact Sheet, 2017. National Chronic Kidney Disease Fact Sheet, 2017.
1. Krishnan M. Preoperative care of patients with kidney disease. *Am Fam Physician*. 2002 Oct 15;66(8):1471-6, 1379. PubMed PMID: 12408421.
1. Domi R, Huti G, Sula H, Baftiu N, Kaci M, et al. From Pre-Existing Renal Failure to Perioperative Renal Protection: The Anesthesiologist's Dilemmas, *Anesth Pain Med.* 2016 ; 6(3):e61545. doi: 10.5812/aapm.32386.

Methodist Debakey Cardiovasc J. 2015 Jul-Sep; 11(3): 197.
doi: 10.14797/mdcj-11-3-197
PMCID: PMC4666432

PMID: 26634033

Administration of Anesthesia to Patients with Renal Failure

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Author information

1. **Never place a central line** in the same extremity where the **arteriovenous access** (primary AV fistula or GORE-TEX® graft) is present.
2. **Do not administer large amounts of intravenous (IV) fluids** to patients with end-stage renal disease (ESRD) or acute renal failure (ARF)-**oliguric patients** (i.e., no more than 1 mL/kg) for **minor procedures** and **during stable clinical conditions**.
3. **Choose the proper IV solution during anesthesia** (0.9% or 0.45% NaCl) **according** to the **following** serum electrolyte levels:
    a. **normal saline (NS) if N_{A^+} < 140 mEq/L**
    b. **½ NS if N_{A^+} > 140 mEq/L or in patients receiving** large amounts of **exogenous N_{A^+}** in the form of *"fresh, frozen plasma".
    c. May **alternate** one liter of each during prolonged surgical procedures, particularly if large amounts of volume are needed. **Add 5% dextrose** in **NS** or **½ NS in nondiabetic patients** or in diabetics who **receive pre-op insulin**.

4. **Severe intraoperative hyponatremia** can frequently happen while receiving hypotonic solutions (< 0.9% NaCl). At **highest** risk are patients with:

    a. ESRD or ARF-oliguria,
    b. post-transurethral resection of the prostate using glycine with or without renal failure, or
    c. endometrial curettage/ablation with or without renal failure.

2. **Do not treat hyperkalemia unless levels of potassium are 6.0 mEq/L** or **above**, in which case use:

a. **dextrose in water (D/W)** 50% mL intravenous push (IVP) **followed** by **5 units (U) IVP regular insulin** as the quickest way to reduce K+ levels by increasing cellular uptake.

Do not use hypertonic glucose with blood sugar **levels > 200 mg/dL**. Use **regular insulin** alone; correction of hyperglycemia results in improvement of hyperkalemia. May use **sliding scale** for blood sugar as follows (using Accu-Chek® every 15 min):

a. 201–250 mg/dL 3 U regular insulin IV
b. 251–300 mg/dL 5 U regular insulin IV
c. 301–350 mg/dL 7 U regular insulin IV
d. 351–400 mg/dL 10 U regular insulin IV
e. 400 mg/dL 15 U regular insulin IV

Conversely, if blood sugar < 100 mg/dL, hyperkalemia should improve with administration of hypertonic glucose alone (50 mL of 50% D/W IVP) without insulin.

b. $NaHCO_3$ 50 mEq (1 amp) IVP **unless** pH is alkalemic (pH > 7.48), in which case **do not administer**.
c. Calcium gluconate 1 gm IVP, particularly if ECG findings of *hyperkalemia are present
An electrocardiogram (ECG or EKG) records the electrical signal from the heart to check for different heart conditions. Watch for hyperkalemia **intra-op** if:
    a. **radiographic contrast** is used (particularly in ARF-oliguric patients, as a consequence of "solvent drag effect"),
    b. **large amounts of mannitol** are given under the same circumstances as above, or
    c. **Cardiovascular collapse develops** with ensuing "lactic acidosis" (resulting in acidemia, "shifting," and hyperkalemia).

3. **For intra-op hypertension** in ESRD and ARF patients, **avoid** ACE inhibitors and beta-blockers as antihypertensive **drugs** since they **can lead** to hyperkalemia. Instead use calcium channel blockers, which may have a **nephroprotective effect** in **ARF patients**.
4. **In patients with acute ongoing metabolic acidosis and acidemia** (pH < 7.30), D/5W 1 liter with 3 amps of $NaHCO_3$ could be used as the solution of choice instead of 0.9% NaCl. Some of these patients could be hyperchloremic; moreover, "expansion acidosis" could further compound the situation. If the patient is hypernatremic (Na^+ levels > 150 mEq/L), tris-hydroxymethyl aminomethane (THAM) is the preferred solution to provide buffer and prevent further worsening hypernatremia obligated by $NaHCO_3$ infusion.
5. **Large amounts of citrate administered via multiple blood transfusions** can lower Ca^{++} levels, for which **calcium gluconate 1 gm IV** should be administered for every 3 U of blood. Ca^{++} levels need to be followed **closely** to **prevent high calcium-phosphorus** double **product** and **risk for calcium-phosphorus precipitation in vital organs**.
6. In the unusual event of severe **hypophosphatemia** (P < 2.0 mg%), replace $NaHPO_4$ 10 mmol IV over 1 hour or $KHPO_4$ 10 mmol over 1 hour according to the situation.
7. **Avoid drugs with potential nephrotoxicity** in ARF patients; modify doses of medications according to reduced renal function (glomerular filtration rate (GFR) < 5 mL in ESRD). Formulas such as MDRD eGFR and Cockroft-Gault *(140 – age in years) × (weight in kg)/SCr × 72* are of no use in ARF to calculate GFR since anuria is GFR 0 regardless of serum creatinine levels; this formula is only useful when renal function is at a steady state and not changing daily as with ARF.

Quizzes:

What anesthesia is used for renal failure patients?

If possible the **shorter acting sedative agents** should be **used for general anesthesia**.
If spinal or epidural anaesthesia is being performed "**fluid preloading**" should be kept to a minimum and "**vasoconstrictors**" **used** to maintain the blood pressure.
Otherwise **postoperative** **fluid overload** may **necessitate dialysis**.

How does Anaesthesia affect renal function?

Inhalational anaesthetics generally reduce glomerular filtration rate and urine output, mainly by extra-renal effects that are attenuated by pre-operative hydration.

The effect of anaesthesia on renal function - PubMed

nih.gov
https://pubmed.ncbi.nlm.nih.gov › ...

Is propofol safe in CKD?

The rather minor pharmacokinetic changes of propofol recorded in patients with end-stage chronic renal failure are in favour of the absence of accumulation of agent, and is a good reason for its use in this context.

[Use of Diprivan in renal insufficiency] - PubMed

nih.gov
https://pubmed.ncbi.nlm.nih.gov › ...

Is propofol safe for kidney disease?

Propofol is commonly used for sedation and general anesthesia in ESKD patients due to rapid recovery after continuous infusion. Previous studies have shown that the pharmacokinetics of propofol are not significantly different between patients with normal kidney function and ESKD [6–8].١٢/ ٠٨/ ٢٠٢١

Potency of propofol for inducing loss of consciousness in end-stage ...

nih.gov
https://www.ncbi.nlm.nih.gov › articles › PMC8360375

Which analgesic is safe for renal?

What analgesics are safe for people who have kidney disease? Acetaminophen remains the drug of choice for occasional use in patients with kidney disease because of bleeding complications that may occur when these patients use aspirin.

Pain Medicines (Analgesics) - National Kidney Foundation

kidney.org
https://www.kidney.org › atoz › content › painmeds_ana...

Is lidocaine safe in renal failure?

Low-dose gabapentin and lidocaine **patches** can be safely used as **adjunctive therapy** in ***renal impaired** and ***dialysis patients**; **TCAs** may also be **used** in **lower** doses in renally **impaired** patients.

Tricyclic antidepressants (TCAs) constitute a class of medications that were initially introduced to the market in 1959 as a pharmacotherapy for major depressive disorder (MDD). [1] TCAs are now regarded as second-line treatment options alongside selective serotonin reuptake inhibitors (SSRIs).

Are depression medications bad for your kidneys? Some antidepressants, such as “tricyclic antidepressants” (TCAs) and “monoamine oxidase inhibitors” (MAOIs), are **generally not** considered **safe** for people with renal failure due to **their potential** to cause adverse effects on the ***cardiovascular and *central nervous systems**.

When are TCAs contraindicated?

Dehydration and **orthostatic hypotension** are contraindications for TCAs, as they may **precipitate falls** or **hypotensive shock**.

Epilepsy: TCAs should also be used with caution in patients with **epilepsy**, as they lower the seizure threshold.١١/ ٠٣/ ٢٠٢٠

TABLE 2

Dosing guide for tricyclic antidepressants in conditions other than depression

Indication	Medications	Initial/ maximum dosing	Dose escalation	Adverse effect management
Headache or migraine	Amitriptyline	10–25 mg/ 100 mg nightly	Individualized: Increase by 10–25 mg every 5–14 days, assess for tolerability and adverse effects Amitriptyline side effects (dry mouth, orthostasis) often limit dose escalation above 100 mg; nortriptyline or maprotiline may be considered (better tolerated at higher doses)	Dry mouth and secretions: Pilocarpine 5 mg 2–3/day Constipation: Stool softeners, eg, docusate sodium, senna glycoside Weight gain: Consider augmenting with metformin 500–1,000 mg/day or topiramate 50–100 mg/day Seizures, QT interval prolongation, active suicidal risk, orthostasis, or falls: Discontinue the agent
Neuropathic pain	Amitriptyline	25–50 mg/ 150 mg nightly (or divided into twice-daily doses if frequent pain or symptom flares)		
Chronic low back pain	Amitriptyline, maprotiline	25–50 mg/ 150 mg nightly		
Fibromyalgia or chronic widespread pain	Amitriptyline, nortriptyline, maprotiline	25–50 mg/ 150 mg nightly (or divided into twice-daily doses if frequent pain or symptom flares)		
Irritable bowel syndrome	Amitriptyline, nortriptyline	10–25 mg/ 100 mg nightly		
Cyclic vomiting syndrome	Amitriptyline, nortriptyline	25–50 mg/ 100 mg nightly		
Chronic pelvic pain, interstitial cystitis, nocturia	Amitriptyline, nortriptyline, imipramine	10–25 mg/ 100 mg nightly		
Insomnia	Amitriptyline, maprotiline, doxepin	25–50 mg/ 150 mg nightly		

What is the analgesic of choice for CKD patients?

Acetaminophen (**Paracetamol**)**remains** the **drug of choice** for occasional use in patients with kidney disease because of bleeding complications that may occur when these patients use aspirin.

How to Manage Pain in Patients with Renal Insufficiency or End-Stage ...

the-rheumatologist.org

https://www.the-rheumatologist.org › article › how-to-m...

Chronic pain is a common symptom experienced by *patients with chronic kidney disease (CKD) and end-stage kidney disease (ESKD) [1,2].

Untreated pain in this population negatively impacts **health related quality of life (HRQOL)**, **dialysis adherence**, healthcare utilization and **mortality** [3-5]; and may contribute to other physical and psychosocial symptoms such as depression, anxiety and fatigue [6].

There is a **disproportionately** high use of **opioids** in this population due to limited availability of non-pharmacological treatment options or safe non-opioid pharmacological options.

In a study of over 400,000 **ESKD patients**, over half had received an opioid prescription, 3.2 times the rate in the US population [7] and 20% were on long term opioid therapy (LTOT) [8].

Chronic opioid use in patients with kidney disease has been **associated with *increased risk of altered mental status, *falls, *fractures, *hospitalizations and *mortality, in a dose-dependent manner** [9-12].

However, closely-monitored LTOT may be **warranted** in some patients who fail to respond to other pain treatments. This requires careful consideration of **risks** and **benefits**.

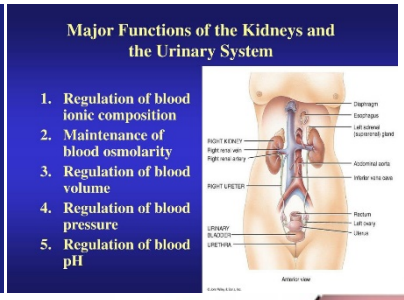
Which drug is not given in renal failure?

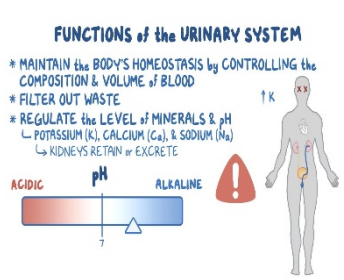
In renal Insufficiency

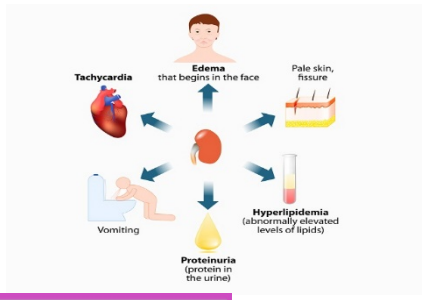
Factors and **conditions** that may worsen the renal injury and **thus** should be either *avoided or *resolved are: **Nephrotoxic drugs** (**NSAIDs, aminoglycosides, iodinated contrast**) Uncontrolled diabetes.٠٧/ ٠٨/ ٢٠٢٣

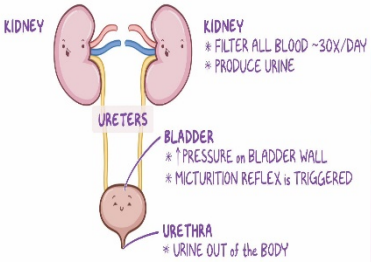
Renal Failure Drug Dose Adjustments - StatPearls - NCBI Bookshelf

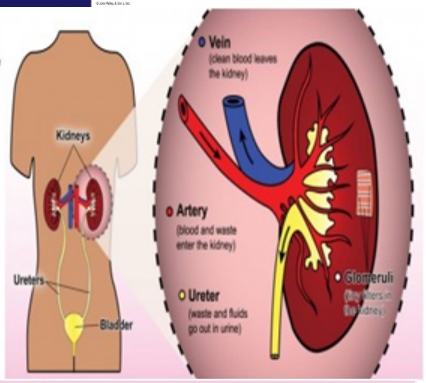

7
Functions of the kidneys

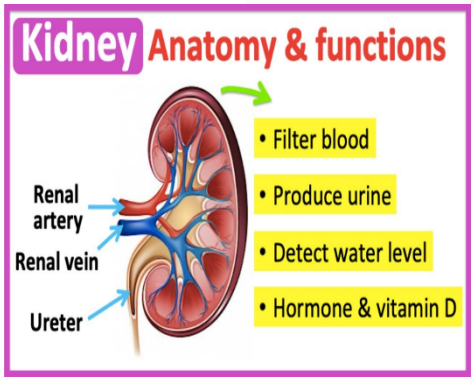

Major Functions of the Kidneys and the Urinary System
1. Regulation of blood ionic composition
2. Maintenance of blood osmolarity
3. Regulation of blood volume
4. Regulation of blood pressure
5. Regulation of blood pH

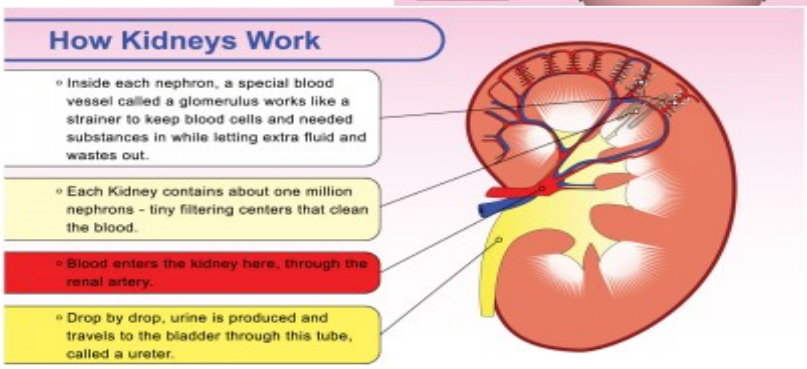

FUNCTIONS of the URINARY SYSTEM
* MAINTAIN the BODY'S HOMEOSTASIS by CONTROLLING the COMPOSITION & VOLUME of BLOOD
* FILTER OUT WASTE
* REGULATE the LEVEL of MINERALS & pH
↳ POTASSIUM (K), CALCIUM (Ca), & SODIUM (Na)
↳ KIDNEYS RETAIN or EXCRETE
↑K
ACIDIC
pH
ALKALINE
7

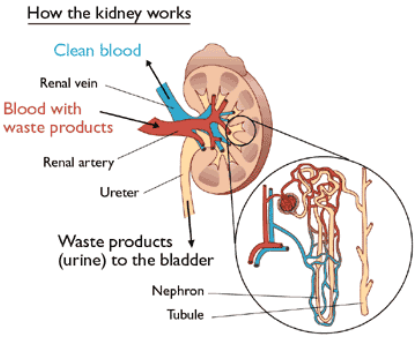

Tachycardia
Edema
that begins in the face
Pale skin, fissure
Vomiting
Hyperlipidemia
(abnormally elevated levels of lipids)
Proteinuria
(protein in the urine)

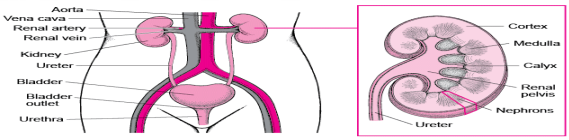

KIDNEY
KIDNEY
* FILTER ALL BLOOD ~30X/DAY
* PRODUCE URINE
URETERS
BLADDER
* ↑PRESSURE on BLADDER WALL
* MICTURITION REFLEX is TRIGGERED
URETHRA
* URINE OUT of the BODY

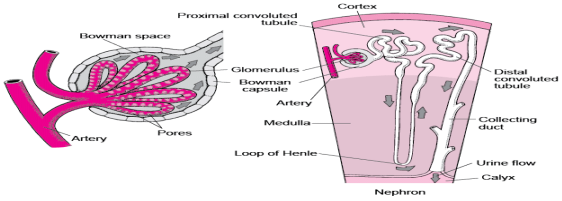

Kidneys
Ureters
Bladder
Vein
(clean blood leaves the kidney)
Artery
(blood and waste enter the kidney)
Ureter
(waste and fluids go out in urine)
Glomeruli


Kidney Anatomy & functions
Renal artery
Renal vein
Ureter
• Filter blood
• Produce urine
• Detect water level
• Hormone & vitamin D

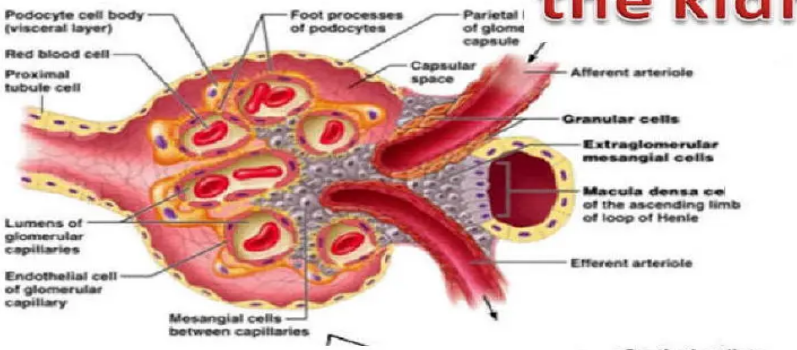

How Kidneys Work
Inside each nephron, a special blood vessel called a glomerulus works like a strainer to keep blood cells and needed substances in while letting extra fluid and wastes out.
Each Kidney contains about one million nephrons - tiny filtering centers that clean the blood.
Blood enters the kidney here, through the renal artery.
Drop by drop, urine is produced and travels to the bladder through this tube, called a ureter.

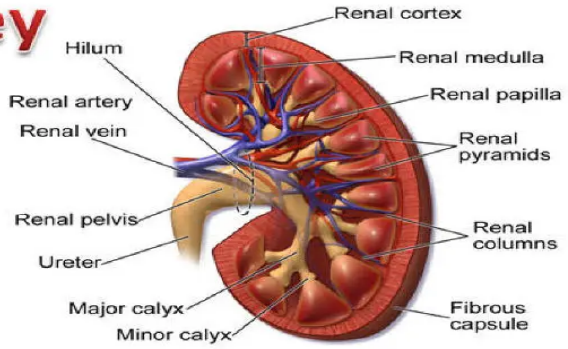

How the kidney works
Clean blood
Renal vein
Blood with waste products
Renal artery
Ureter
Waste products (urine) to the bladder
Nephron
Tubule

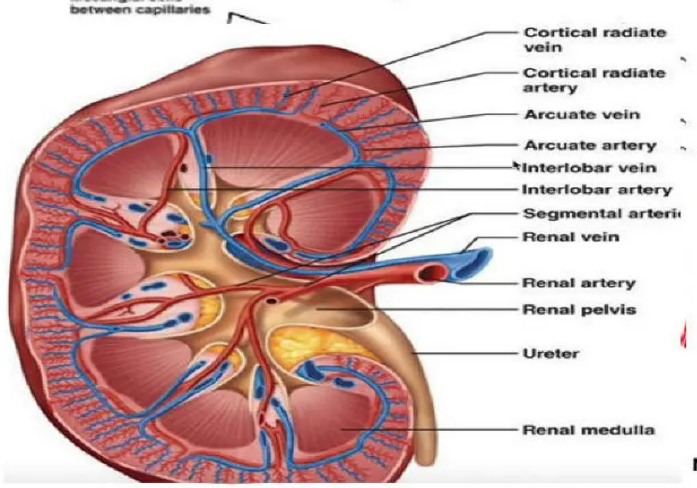

Aorta
Vena cava
Renal artery
Renal vein
Kidney
Ureter
Bladder
Bladder outlet
Urethra
Cortex
Medulla
Calyx
Renal pelvis
Nephrons
Ureter

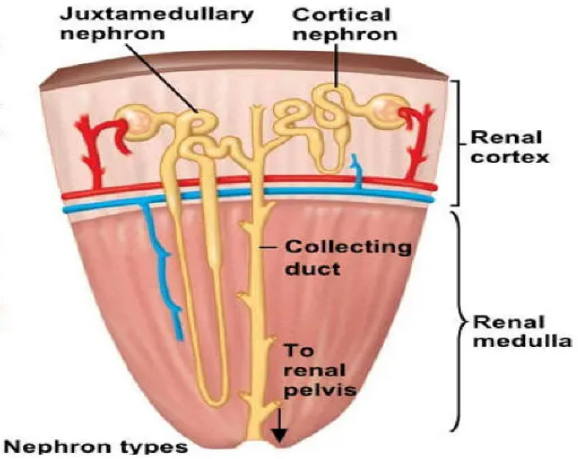

Proximal convoluted tubule
Bowman space
Glomerulus
Bowman capsule
Artery
Pores
Cortex
Distal convoluted tubule
Collecting duct
Medulla
Loop of Henle
Urine flow
Calyx
Nephron

the kidney


Podocyte cell body (visceral layer)
Red blood cell
Proximal tubule cell
Foot processes of podocytes
Parietal of glome capsule
Capsular space
Afferent arteriole
Granular cells
Extraglomerular mesangial cells
Macula densa ce of the ascending limb of loop of Henle
Lumens of glomerular capillaries
Endothelial cell of glomerular capillary
Efferent arteriole
Mesangial cells between capillaries


Renal cortex
Hilum
Renal medulla
Renal papilla
Renal artery
Renal vein
Renal pyramids
Renal pelvis
Renal columns
Ureter
Major calyx
Fibrous capsule
Minor calyx


Cortical radiate vein
Cortical radiate artery
Arcuate vein
Arcuate artery
Interlobar vein
Interlobar artery
Segmental arteri
Renal vein
Renal artery
Renal pelvis
Ureter
Renal medulla


Juxtamedullary nephron
Cortical nephron
Renal cortex
Collecting duct
Renal medulla
To renal pelvis
Nephron types