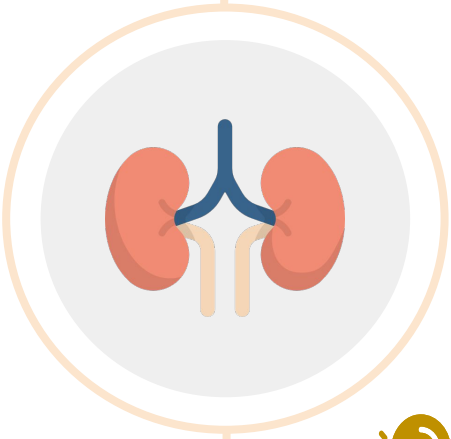
Acute Kidney Injury



Online MedEds High-Yield Brilliant Summary!

Objectives :

- ★ Define Acute Kidney Injury (AKI)
- ★ Discuss the epidemiology of AKI
- ★ Discuss the etiology of AKI
- ★ Describe the management of AKI
- ★ Diagnose AKI
- ★ Treat AKI

MED439

Medicine Team 439

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Acute kidney injury (Acute renal failure)

Definition of AKI[1]

- Deterioration of renal function[2] over a period of **hours to days**, resulting in the **failure**[3] of the kidney to:
  1) **Excrete nitrogenous waste products.**
  2) **Maintain Fluid & electrolyte homeostasis.**
- **Oliguria**: < **400** ml/cc urine output in 24 hours.
- **Anuria**: < **100** ml/cc urine output in 24 hours.

◀ Acute renal failure definition[4]

ARF in one study was defined as:

- **0.5** mg/dL: Increase in serum creatinine if the baseline serum creatinine was **≤ 1.9** mg/dL.
- **1.0** mg/dL: Increase in serum creatinine if the baseline[5] serum creatinine was **2.0 to 4.9** mg/dL.
- **1.5** mg/dL: Increase in serum creatinine if the baseline serum creatinine was **≥ 5.0** mg/dL.

◀ AKI "RIFLE" definition

	GFR/Creatinine criteria	Urine Output criteria
Risk	• Increase in creatinine x1.5 **Or** • GFR decrease > 25%	• UO < 0.5 ml/kg/hr for 6 hrs.
Injury	• Increase in creatinine x2 **Or** • GFR decrease > 50%	• UO < 0.5 ml/kg/hr for 12 hrs.
Failure	• Increase in creatinine x3 **Or** • GFR decrease > 75%	• UO < 0.3 ml/kg/hr for 24 hrs. **Or** • Anuria for 12hrs.
Loss	Persistent ARF = complete loss of renal function > 4 weeks.	
ESRD	End Stage Renal Disease > 3 months.	

1: More than 28 definitions of AKI are mentioned in literature.
2: The kidney has 5 functions: 1. Excretion of waste products 2. Water homeostasis 3. Electrolyte homeostasis 4. Acid-base balance 5. Endocrine function (Erythropoietin which regulates anemia & BP regulation through renin which is important). The first 3 function are usually not affected in mild disease.
3: Loss of renal functions depends on severity. If is was mild disease, these abnormalities won't be seen compared to severe disease which most abnormalities are seen
4: Old definition, not accurate because of differences between studies findings
5: Baseline creatinine value should be considered as the patient's 'usual' creatinine when clinically well, determine by reviewing patient's previous blood results within clinical context. Assume normal baseline if no previous blood tests.

Acute kidney injury

◀ AKI Network definition[1]

	Creatinine criteria (Based on serum creatinine baseline.)	Urine Output criteria (Depends on urine output reduction.)
Stage I	• 1.5-2 times baseline[2]. **Or** • 0.3 mg/dL increase from baseline (≥ 26.4 µmol/L).	• UO < 0.5 ml/kg/h for > 6 hrs.
Stage II	• 2-3 times baseline.	• UO < 0.5 ml/kg/hr for > 12 hrs.
Stage III	• 3 times baseline. **Or** • 0.5 mg/dL (44 µmol/L) increase if baseline > 4 mg/dL (≥ 354 µmol/L). **Or** • Any renal replacement therapy given.	• UO < 0.3 ml/kg/hr for > 24 hrs. **Or** • Anuria for > 12hrs.

"Acute kidney injury, mortality, length of stay, and costs in hospitalized patients"

- 19,982 pts admitted to academic medical centre in SF 9,205 pts with > 1 creatinine results:

Rise in creatinine[3]	Multivariable or (hospital mortality)
≥ 0.3 mg/dL (26.4 µmol/L)[3]	4.1 (lowest)
≥ 0.5 mg/dL (45 µmol/L)	6.5
≥ 1.0 mg/dL (90 µmol/L)	9.7
≥ 2.0 mg/dL (180 µmol/L)[4]	16.4 (highest)

◀ AKI "KDIGO" definition[4]

- **An abrupt (within 48 hours)** with no abnormal prior reading **(normal baseline):**
  - **Absolute increase** in creatinine by **0.3** mg/dL **(26.4 µmol/L)**
  - OR Percentage increase of **> 50%** from baseline.
  - OR Urine output[5] **< 0.5** ml/kg/hour for 6 hours.
- **Acute:** >26.4 µmol/L increase in creatinine within 48 hours
- Chronic: e.g. baseline: 280 and current creatinine is 285
- Acute on top of chronic: e.g. baseline is 150 and current creatinine is 285

- Acute occurs when there is an increase of creatinine above 26.4 µmol/L within 48 hours with a normal baseline
- Chronic occurs when the patient has (an abnormal baseline that is elevated) for over 3 months وقيمة الارتفاع هذي تكون ثابتة
- Acute on top of chronic occurs when there is an increase of creatinine levels within a short period of time over with an abnormal baseline that is elevated)

1: Nephrologists tried to refine the "RIFLE" definition more. يوحدون التعريف لأنه كان مختلف من مكان لمكان ومن دراسة لأخرى
2: Specific numbers are given compared to the "RIFLE" definition.
3: Problem with creatinine that it peaks within 10-24 hours. So nephrologists tried to measure at what stage rise in creatinine have an impact, so they looked at the odd ratio of mortality. **"26.4 µmol/L"** was chosen because it is the lowest value of creatinine that can result in mortality
4: latest definition in 2009
5: Was included because it precedes serum creatinine, so it will be noticed first

Acute kidney injury

◀ Epidemiology & Incidence of AKI

- **AKI occurs in:**
  - **5%** of of all hospitalized patients, and **35%** of those in intensive care units, because of:
    - Comorbidities e.g. diabetes, HTN, CKD
    - Patients with infections, respiratory failure, HF, use of nephrotoxic medications
    - Patient in ICU are in hypotensive state most of the time.

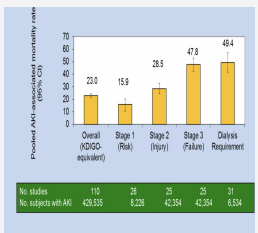
- **Mortality in ICU patients is high:**
  - Up to **75–90%** in patients **with sepsis** and septic shock
  - **35–45%** in those **without sepsis,** much better prognosis

◀ Impact & outcome of AKI

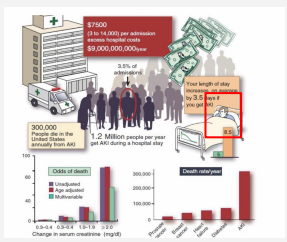
- **Correlation between AKI classification and outcome**
  - 22,303 adult patients admitted to 22 ICUs in UK and Germany between 1989–1999 with ICU stay ≥ 24 hours.

	No AKI (65.5%)	AKI I (19.1%)	AKI II (3.8%)	AKI III (12.5%)
Mean age	60.5	62.1	60.4	61.1
ICU mortality	10.7%	x2 20.1%	25.9%	x2 49.6%
Hospital Mortality	16.9%	29.9%	35.8%	57.9%
Length of stay in ICU (median)	2 d	5 d	8 d	9 d

- "Long-term risk of mortality and other adverse outcomes after AKI: A systematic review and meta-analysis"
  - 48 studies, 47,017 patients with AKI (varying criteria) Length of follow-up: 6 months – 17 years.
-
- **Acute kidney injury associated with:**
  - Increased risk of CKD.
  - Increased risk of CV event
  - Increased long-term mortality.



Message out of this picture is the more severe the disease the higher the mortality.

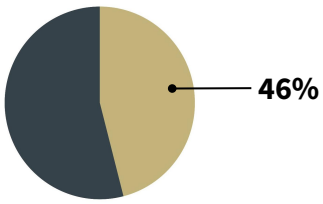


Esp. sepsis and septic shock

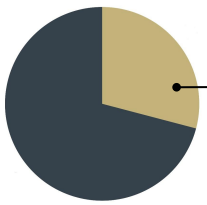
Acute kidney injury

◀ Risk of Chronic kidney disease (CKD)

- Increasing evidence that episodes of AKI leave permanent renal damage.
- Long-term prognosis after AKI requiring RRT (Renal replacement therapy):
  - **206 ICU patients with RRT for AKI.**
  - Single centre in Geneva.



90 day survival



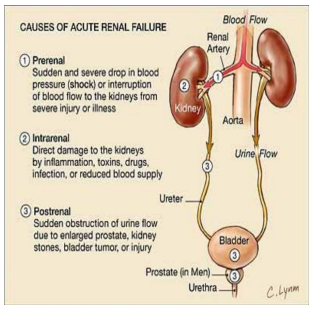
20/60 (41.7%): New CKD
9/60 (15%): ESRD, on dialysis

3 years post ICU

◀ Overview of Types AKI[4]:

1- Prerenal AKI[1]: Any condition that leads to reduced renal perfusion

- Volume depletion.
- Decrease cardiac output.
- Drugs
- ~60% of cases



2- Renal AKI[2]: Any condition leading to severe direct kidney injury

- Acute tubular necrosis (ATN).
- Acute interstitial nephritis (AIN).
- Acute Glomerulonephritis (GN).
- ~35% of cases

3- Post renal AKI[3]: Obstruction to urine flow at any point from the tubule to the urethra.

- Ureteric obstruction.
- Bladder neck obstruction.
- Urethral obstruction.
- ~5% of cases

◀ Acute vs chronic kidney disease

	Acute	Chronic
History	Short (days-week)	Long (month-years)
Haemoglobin	Normal except bleeding	Low
Renal size by US	Normal	Reduced Except: DM, amyloidosis (normal size)
Serum creatinine	Acute reversible increase	Chronic irreversible increase

1-above kidney (blood vessels and heart). Consider history to differentiate between them, lab (high urine osmolarity (concentrated), low urine Na)
2- (Interstitium, glomerulus, tubules)
3- below kidney(ureter, bladder, urethra, prostate) . Doesn't cause AKI unless the kidney is unhealthy or/and it's **bilateral** obstruction; Lab: (urinalysis = normal Na , normal osmolarity, +/- WBC)

Pre-renal AKI

Pathophysiology

↓ Blood supply to kidneys → failure of renal vascular autoregulation to maintain renal perfusion → ↓ **GFR leading to azotemia (urea and creatinine isn't filtered out of the body)**→ activation of renin-angiotensin system → ↑ aldosterone release → **↑ reabsorption of Na+, H2O** → **increased reabsorption of urea** → ↑↑ urea in the blood→ ↑ BUN ratio.

- Persistence of hypotension can lead to renal AKI

Causes

Volume depletion:

- Renal losses: diuretics, polyuria
- GI losses: vomiting, diarrhea
- Cutaneous losses: burns, Stevens- Johnson syndrome (A rare immune-mediated skin reaction leads to extensive epidermal detachment)
- Hemorrhage:
  - Internal (peptic ulcer)
  - External (Car accident)
- Pancreatitis: Third spacing is the movement of bodily fluid from the blood, into the spaces between the cells: in this case there is extravasation of fluid from pancreas to abdomen)

Decreased cardiac output

- Heart failure
- Pulmonary embolism
- Acute myocardial infarction
- Severe valvular heart disease
- Abdominal compartment syndrome (tense ascites)
- Sepsis, cardiogenic shock resulting in hypotension

Drugs

- Diuretics
- **ACE inhibitors** (efferent arteriole vasodilation)
- ARBs
- NSAIDs (constrict afferent arterioles)
- calcineurin inhibitors (e.g. cyclosporine)
- Iodinated contrast

Features

- **Clinical presentation depends on the underlying cause.** e.g.
  - HF pts presents with SOB, edema, ↑JVP
  - Pts with nausea, vomiting or diarrhea present with ↓JVP, tachycardia, dry mucous membranes
- **Signs of volume depletion**
- **Urine:**
  - **Concentrated** (high osmolality, >350) therefore ↑urine specific gravity (USG). Urine specific gravity correlates to urine osmolality. High UOsm = High specific gravity
  - ↓Urine Na because kidney is intact (FENa < 1%) Urine sodium and FE Na give you the same information.
- Urine analysis is normal. no protein urea, WBCs or RBCs

It is important to note that prerenal AKI may also occur without systemic hypotension, particularly in patients taking NSAIDs or ACE inhibitors

Treatment

Depends on the underlying cause

- HF: diuretics to decrease load on the heart and BP regulators for better perfusion. Treating the patient with fluid replacement will increase the load on the heart making the situations worse.
- Diarrhea and vomiting: fluid replacement

Renal AKI

Acute tubular necrosis (ATN)

Pathophysiology	• Necrotic tubular cells fall into the tubular lumen → debris obstructs tubules → ↓ GFR → sequence of pathophysiological events similar to prerenal failure • **It is the most common cause of renal AKI**
Causes	**Ischemic** (injury **secondary** to decreased blood flow): the blood vessels "vasa recta" supply tubules are very thin as hair so it's very sensitive for any vascular problem as CHF, bleeding and atherosclerosis • Prolonged hypotension **(e.g. shock)** • Sepsis • **Prolonged prerenal state** (prolonged hypoperfusion → necrosis of tubules)
	Toxic: (injury occurs **directly** due to nephrotoxic substances) • **Heme pigment** (myoglobin and hemoglobin): **rhabdomyolysis**, intravascular hemolysis. • **Crystals**: tumor lysis syndrome (High uric acid), seizures, ethylene glycol poisoning (Oxalate), megadose vitamin C, acyclovir, indinavir, methotrexate. BJ proteins in multiple myeloma • **Drugs**: **aminoglycosides**, lithium, amphotericin B, pentamidine, cisplatin, ifosfamide, radiocontrast agents, tenofovir, ACEIs
Diagnosis	Made by clinical features of the causal condition together with features of rapidly progressive uremia (anorexia, nausea, vomiting and pruritus), **hyperkalemia** (Due to release of K+ from damaged cells because 95% of the potassium in the body is intracellular, sometimes the first step in managing AKI would be an ECG and calcium gluconate, especially in cases of rhabdomyolysis and crush syndrome), **metabolic acidosis**. • History • ↑ FENa (>2%) sediment • Urine: muddy brown, coarse **granular casts** in urine (as a result of sloughed necrotic tubular cells)
Treatment	**Supportive care:** • Maintenance of euvolemia: with diuretics e.g. in HF, IVF as necessary) • Avoidance of hypotension • Avoidance of nephrotoxic medications. including NSAIDs, methotrexate, and ACE-I • Dialysis, if necessary 80% will recover, tubules will regenerate if initial insult can be reversed.

◀ Comparison between Pre renal & ATN[2]

	Pre renal	ATN
Urea/Creatinine ratio	> 20:1	10-15:1
Urine	Normal	**Muddy brown casts**
Urine Osmolality	> 500	**< 350**
Urine specific gravity	> 1.020	< 1.010
Urine Na	< 20	**> 20**
Fractional excretion of Na (FENa)	< 1%	> 1%

- Fraction excretion of Na:
  - FENa < 1%: prerenal AKI
  - FENa >1%: renal AKI

$$FE_{Na} = \frac{U_{Na} * P_{Cr}}{P_{Na} * U_{Cr}} * 100$$

What is the difference between creatinine & BUN (blood-urea nitrogen)? And when do we depend on each one?
We always depend on creatinine for assessing kidney function, while we don't depend much on BUN to assess that.

Why?
Because Urea gets reabsorbed by the kidneys, while creatinine doesn't. So BUN doesn't reflect the filtration rate (GFR), and therefor doesn't tell us about the kidney function.

Whenever creatinine gets filtered, it's not stolen back by the kidney. This makes us rely on creatinine but not on urea for assessing kidney function.

If that's the case, then when can we depend on BUN?
We depend on BUN when the patient is volume depleted for example. This is because the body reabsorbs Na & water, and also reabsorbs other solutes like urea. So when we see high blood urea, we know that the body is trying to compensate for the fluid loss.

Renal AKI

Acute interstitial nephritis

Acute inflammation of the renal interstitium and tubules that causes a decline in renal function

Causes	• **Drugs** 70%: Drug-induced acute interstitial nephritis is harder to spot but should be suspected in a previously well patient if there is an acute deterioration of renal function coinciding with introduction of a new drug treatment. ○ **Penicillin**, sulfa drugs, phenytoin, rifampin, quinolones, allopurinol, **PPIs**, **NSAIDs** • **Infection.** Viruses, e.g. hantavirus. Bacteria, e.g. streptococci • **Systemic diseases** e.g. Sjogren syndrome (which may cause interstitial nephritis, Lupus, Infection, IBD),

Diagnosis	Could be asymptomatic or present with rash and a history of injections e.g. penicillins, cephalosporins etc.
	• History of systemic disease known to be associated with AIN.
	• Skin rash
	• Eosinophilia
	• **Urine**
	  ○ **WBCs and WBCs casts**
	  ○ **Negative urine culture: Sterile pyuria** (eosinophiluria). That's how you differentiate between infection and interstitial nephritis bc both have WBCs in urine
	• Renal biopsy

Treatment	D/c offending agent, conservative, may use steroids

Acute glomerulonephritis

Mainly GN causes AKI If the presentation is Rapidly progressive GN:

Causes	Could be primary (e.g.Membranous, Minimal change, Focal segmental glomerulosclerosis, IgA etc.) OR Secondary (Caused by DM, Lupus etc.).
	Anti-GBM antibody Immune complex:
	• Post-infectious (streptococcal infection).
	• Connective tissue disease:
	  ○ Lupus nephritis
	  ○ Henoch-Schönlein purpura
	• Membranoproliferative glomerulonephritis (MPGN)
	
	Pauci-immune (Vasculitis):
	• Wegener granulomatosis (WG).
	• Microscopic polyangiitis (MPA).
	• Churg-Strauss syndrome.

Clinical features	• Symptoms and signs of systemic disease. • Non specific: lower limb swelling, **hematuria**, frothy urine. • Symptoms and signs of ESRD.
Diagnosis	• **Urine:** RBCS and RBC casts[1], proteinuria • By serology: ANCA, anti-GBM, ANA, C3 and C4, Viral hepatitis B & C screen, HIV. • **Then do renal biopsy and according to the findings we treat them**
Treatment	• General. • **Disease specific:** Steroid,Immunosuppressive agents, Plasmapheresis.

1- Tamm-Horsfall proteins: regular protein produced in the PCT that forms a waxy matrix. In case of glomerulonephritis, we will have↑RBC. Some of these RBC will combine to the protein and form a urinary (shape of a tubule) cast (RBC cast)

Renal AKI

Contrast induced AKI

Definition	• AKI post IV administration of iodinated contrast medium • **12-24 (up to 48) hours post exposure** • Creatinine peaks in 3-5 days
Risk factors	CKD, older age, hypovolemia, DM, CHF, Myeloma, NSAIDs, Hypotension, Anemia, Dehydration
Prevention	• Always evaluate kidney function before administering contrast agent • Use alternative procedure if feasible • Ensure hydration before and after administration of contrast medium
Treatment	• 1/2 NS 1 cc/kg/hr 12 hours pre/post • N-acetyl cysteine 600 BID pre/post (4 doses). • Monitoring of urine output. Creatinine and lytes.

Atheroembolic AKI or Cholesterol embolization syndrome

Definition	Embolization of cholesterol released from atherosclerotic plaques or common vessel wall deposits
Causes	• Commonly occur after intravascular procedures or cannulation (cardiac cath, CABG, AAA repair, etc.), • **Can occur in patients with atherosclerosis after plaque rupture** • Anticoagulants, thrombolytic agents
Features	• Evidence of other embolic phenomena-CVA • Ischemic digits (“blue toe” syndrome) absent pulses • **Skin involvement: (livedo reticularis, purpura,** necroses) • CNS symptoms • Low serum C3 and C4 • Peripheral eosinophilia, eosinophiluria
Treatment	• **S**upportive, dialysis in the only management option. • In general prognosis is poor: 2-year mortality (30%), CKD (30%)

◀ Consequences of AKI

- Hospitalization
- Mortality
- CKD
- ESRD

Post renal AKI

Pathophysiology	• **Bilateral urinary outflow obstruction** → increased retrograde hydrostatic pressure within renal tubules → decreased GFR and compression of the renal vasculature → acidosis, fluid overload, and increased BUN, creatinine, Na+, and K+ NOTE: If obstruction is unilateral they will not have AKI, unless they have one kidney only. A normal GFR can be maintained as long as one kidney functions normally. **Both kidneys must be obstructed for the creatinine to rise.**
Causes	**Bladder neck obstruction:** 1. Benign prostatic hypertrophy [BPH] 2. Cancer of the prostate 3. Neurogenic bladder 4. Drugs (Tricyclic antidepressants, ganglion blockers) 5. Bladder (tumor, tone disease, hemorrhage/clot) 6. Congenital bladder neck obstruction

	• **Ureteric obstruction:**
	  ○ Stone disease
	  ○ Tumor
	  ○ Retroperitoneal fibrosis
	  ○ Ligation during pelvic surgery.
	  ○ Ureteric stricture (tuberculosis, especially after treatment; calculus; after surgery)
	  ○ Congenital megaureter
	• **Urethral obstruction**: strictures, **tumor**

Features	• Could be asymptomatic • Flank pain • Hematuria • Tumor or BPH symptoms (weak stream, post-void-dribbling, overflow incontinence) • In severe cases urine output is zero • Suprapubic pain and tenderness • Examination: **usually unremarkable** unless they have lymph node problem or tumor.
Diagnosis	Urine osmolality is usually normal **if** there was urine output Urinalysis: • Usually normal • Occasional hematuria Imaging studies: **Diagnostic** • Should undergo imaging with ultrasound to detect evidence of obstruction above the level of the bladder. Usually accompanied by hydronephrosis. • **We can't rule out post-renal without US or other imaging modalities**
Treatment	Treat the underlying cause **Obstruction should be relieved as soon as possible.** • Foley catheter: **only** urethral or prostatic obstruction, not useful for anything higher • Nephrostomy tube if obstruction was above the urethra • Percutaneous nephrostomy.

◄ Indications for dialysis In AKI setting

A-E-I-O-U

- Symptoms of uremia e.g. encephalopathy
- Uremic pericarditis
- Refractory volume overload
- Intoxication
- Refractory hyperkalemia
- Refractory metabolic acidosis
  e.g. patient is not responding to administration of sodium bicarbonate

Extra

Cause	Prerenal	Renal	Postrenal
BUN:creatinine ratio	>20:1	<15:1	Varies
FENa	<1%	>2-3 %	
FEUrea	<35%	>50%	
Urine Na concentration	<20 mEq/L	>40 mEq/L	
Urine osmolality	**>500 mOsm/kg**	**<350 mOsm/kg**	**<350 mOsm/kg**
Urine sediment	Hyaline cast	• Renal tubular epithelial cells or granular, **muddy brown,** or pigmented casts (e.g. due to ATN) • **RBC casts** (e.g. due to glomerulonephritis) • **WBC casts** (e.g. due to allergic interstitial nephritis)	• Hematuria (stones, bladder cancer, clots) • Absent (neurogenic bladder)

- Urine osmolality is proportionate to specific gravity, high urine osmolality means that kidneys are reabsorbing well, and that, tubules are intact (urine is concentrated). In pre-renal AKI, the primary issue is hypoperfusion → kidneys do their usual work by reabsorbing sodium to preserve fluid (hence the FENa is low and osmolality of urine is high, in contrast to renal AKI, tubules are damaged, reabsorption is compromised and more sodium will get excreted (high FENa) but water is also excreted in large amounts hence the low osmolality of urine in renal AKI
- Patients with prerenal AKI receiving diuretic therapy may have a falsely elevated FENa. Therefore, FEUrea may be more informative in this setting-
- Avoid co administering RAAS inhibitors and NSAIDs in patients with reduced renal perfusion (e.g., in congestive heart failure, renal artery stenosis) because doing so can significantly decrease their GFR.
- The longer the underlying cause has been present, the greater the chance that AKI will progress to renal failure and/or CKD. Treat potential causes of AKI early.

◀ Four phases of AKI (some patients may not undergo all phases)

Initiating event (kidney injury)	Symptoms of the underlying illness causing AKI may be present	Hours to days
Oliguric or anuric phase (maintenance phase)	• Progressive deterioration of kidney function - Reduced urine production (oliguria), ,50ml/24 hrs= anuria - Increased retention of urea and creatinine (azotemia) • Complications: fluid retention (pulmonary edema), hyperkalemia, metabolic acidosis, uremia, lethargy, asterixis.	~ 1 weeks
Polyric/diuretic phase	• Glomerular filtration returns to normal, which increases urine production (polyuria), while tubular reabsorption remains distubed. • Complications: loss of electrolytes & water (dehydration, hyponatremia, and hypokalemia)	2 weeks
Recovery phase	• Kidney function and urine production normalize (in some cases, kidney function remains permanently compromised)	years to months

Cases

◄ Case study 1:

- 50 years old Saudi male status post right hemicolectomy 6 hours ago for colon cancer intraoperative course complicated by bleeding and hypotension required 6 units of blood transfusion urine output decreased significantly serum creatinine 285µmol/L?
- Patient is previously healthy
- **JVP was low, cold periphery**
- CVS examination: normal 1st and 2nd heart sounds, no added sounds or murmurs
- Respiratory system: lungs are clear to percussion and auscultation
- Abdominal examination: no tenderness, liver and spleen were not palpable

Vital signs	Result	Normal range
Pulse	**134/ min**	60-100/ min
BP	**80/55 mmHg**	130/80 mmHg
Temperature	37.0 C	36.6-37.2 C

CBC	Result	Normal range
Hb	**70 g/L**	Male: 135-175 g/L Female: 120-155 g/L
WBC	**12 x 10* 9/L**	4.5-11 x 10*9/L
Platelets	**198 x 10*9/L**	140-450 x 10*9/L

Test	Value	Normal values
Creatinine	**285 µmol/L**	62-115 µmol/L
Urea	**29 mmol/L**	2.5-6.4 mmol/L
Potassium	**6.2 mmol/L** (hyperkalemia)	3.5-5.1 mmol/L
Sodium	137 mmol/L	135-145 mmol/L
Bicarbonate	**16 mmol/L** (metabolic acidosis)	22-26 mmol/L
Specific gravity	1.003 Low (diluted urine)	1.015-1.025

Urine	Result	Normal values
Color	Dark yellow	Amber yellow
Character	Clear	Clear
PH	6 acidic	4.8-8
Specific gravity	1.003	1.015-1.025
Protein	+2	-
Glucose	-	-
RBCs	1-2/hpf	-
Hemoglobin	-	-
Pus cells (WBC)	1-2/hpf	
Amorphus phosphate		
Bacteria	-	-
Granular casts	Seen	

◄ Approach:

- **Approach to a patient with high creatinine:**
  - **Step one:** compare baseline creatinine to current creatinine levels to specify which type of kidney injury does the patient have (acute/ chronic/ acute in top of chronic).
    - **Acute:** >26.4 µmol/L increase in creatinine within 48 hours
    - Chronic: e.g. baseline: 280 and current creatinine is 285
    - Acute on top of chronic: e.g. baseline is 150 and current creatinine is 285
  - **Step two: if its acute determine the etiology (prerenal, renal or postrenal)**
    - In this case, we can start by excluding post-renal (by his history). so it could be prerenal or renal
    - Prolonged bleeding and hypotension = could be prerenal due to hypoperfusion (bleeding)
    - **Patient is in shock,** physiologically kidney is supposed to excrete concentrated urine by reabsorption of Na & K to maintain body volume. Diluted urine in this case means that the **kidney is not functioning properly= renal cause** (6 units of blood is not simple, so it result in ischemia to the tubules)
- **Diagnosis:** Acute Kidney Injury secondary to Acute tubular necrosis due to shock (prolonged hypotension)
- **Treatment:** Maintain the blood volume, avoid the cause, monitor the patient

Cases

◄ Case study 2:

- 75 years old female, known to have DM II & HTN, Presented with nausea, vomiting and diarrhea for 3 days, she is on Insulin and **lisinopril**. **Baseline creatinine is (70 µmol/L)**
- **JVP was low, dry mucus membranes**
- CVS examination: normal 1st and 2nd heart sounds, no added sounds or murmurs
- Respiratory system: lungs are clear to percussion and auscultation
- Abdominal examination: no tenderness, liver and spleen were not palpable

Vital signs	Result	Normal range
Pulse	**95/ min**	60-100/ min
BP	**112/67 mmHg**	130/80 mmHg
Temperature	37.0 C	36.6-37.2 C

CBC	Result	Normal range
Hb	**134 g/L**	Male: 135-175 g/L Female: 120-155 g/L
WBC	**12 x 10* 9/L**	4.5-11 x 10*9/L
Platelets	198 x 10*9/L	140-450 x 10*9/L

Test	Value	Normal values
Creatinine	154 µmol/L	62-115 µmol/L
Urea	23 mmol/L	2.5-6.4 mmol/L
Potassium	4.3 mmol/L	3.5-5.1 mmol/L
Sodium	137 mmol/L	135-145 mmol/L
Bicarbonate	20 mmol/L	22-26 mmol/L

Urine	Result	Normal values
Color	Dark yellow	Amber yellow
Character	clear	clear
PH	6 acidic	4.8-8
Specific gravity	1.025	1.015-1.025
Protein	**+1**	-
Glucose	-	-
RBCs	1-2/hpf	-
Hemoglobin	-	-
Pus cells (WBC)	1-2/hpf	
Amorphus phosphate		
Bacteria	-	-
Granular casts		

◄ Approach:

- **Approach to a patient with high creatinine:** you can tell the cause is **prerenal** based on the history
  - **Step one:** determine the baseline of creatinine to specify which type of kidney injury**. Baseline creatinine is (70 µmol/L)**
    - Acute
  - **Step two:** determine the etiology (prerenal, renal or postrenal)
    - In this case, we can start by saying that the case favors prerenal etiology (hypovolemia)
    - now:
      1: Check for urine concentration (specific gravity): concentrated (kidney is functioning well), if diluted= renal (ATN)
      2: Check for sodium: Normal
- **Diagnosis:** Acute kidney injury
- **Etiology:** Prerenal (dehydration).
- **What do you expect to find in urine analysis?** Normal.
- **What do you expect urinary Na, osmolality?** Urinary Na<10 ,Osmolality > 300 ,Fractional excretion of Na <1%
- **Treatment:** IV fluid

Cases

◀ Case study 3:

- 19 years old girl known to have: Inflammatory bowel disease, referred for evaluation of **high serum creatinine 320 µmol/l, creatinine baseline 90 µmol/l July 2015, creatinine of 160 µmol/l June 2017, Creatinine (250 µmol/l) 2 weeks ago.**

IBD are predisposed to prerenal AKI (diarrhea, vomiting or sepsis), renal AKI, and postrenal AKI (calcium oxalate stones or obstruction of the ureters due to inflammation)

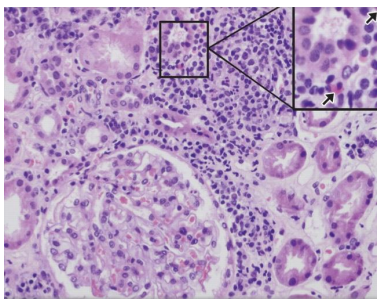
- **JVP was normal**
- CVS examination: normal 1st and 2nd heart sounds, no added sounds or murmurs
- Respiratory system: lungs are clear to percussion and auscultation
- Abdominal examination: no tenderness, liver and spleen were not palpable

Vital signs	Result	Normal range
Pulse	95/ min	60-100/ min
BP	123/67 mmHg	130/80 mmHg
Temperature	37.0 C	36.6-37.2 C

CBC	Result	Normal range
Hb	**146 g/L**	Male: 135-175 g/L Female: 120-155 g/L
WBC	13 x 10* 9/L	4.5-11 x 10*9/L
Platelets	198 x 10*9/L	140-450 x 10*9/L

Test	Value	Normal values
Creatinine	**320 µmol/L**	62-115 µmol/L
Urea	10 mmol/L	2.5-6.4 mmol/L
Potassium	4.3 mmol/L	3.5-5.1 mmol/L
Sodium	137 mmol/L	135-145 mmol/L
Bicarbonate	22 mmol/L	22-26 mmol/L

Urine	Result	Normal values
Color	Dark yellow	Amber yellow
Character	clear	clear
PH	6 acidic	4.8-8
Specific gravity	1.025	1.015-1.025
Protein	+1	-
Glucose	-	-
RBCs	1-2/hpf	-
Hemoglobin	-	-
Pus cells (WBC)	30-40/hpf	
Amorphus phosphate		
Bacteria	-	-
Granular casts	WBC casts	



◀ Approach:

- **Approach to a patient with high creatinine:**
  - **Step one:** determine the baseline of creatinine to specify which type of kidney injury**. Baseline creatinine: 160 µmol/L**
  - Acute on top of chronic (due to high abnormal baseline)
  - **Step two:** determine the etiology (prerenal, renal or postrenal)
    - in this case, Normal pulse and BP exclude prerenal and ATN
    - Abnormal urinalysis exclude postrenal
    - WBC, WBC and eosinophils indicate **AIN** (biopsy was taken to confirm the diagnosis)
- **What does the microscopic picture show?** Prominent interstitial infiltration by WBCs.
- **Diagnosis:** AKI in top of chronic secondary to interstitial nephritis.
- **Treatment:** Look for offending agent, steroid.

Cases

◄ Case study 4:

- 19 years old Saudi male, status post road traffic accident seven months ago, **bedridden**, on **folly's catheter**, you have been called to see the patient because of **high serum creatinine is 198 µmol/l. Baseline creatinine 45 µmol/l two days ago, Urine output 1.2 L/day.**
- **JVP was normal**
- CVS examination: normal 1st and 2nd heart sounds, no added sounds or murmurs
- Respiratory system: lungs are clear to percussion and auscultation
- Abdominal examination: no tenderness, liver and spleen were not palpable

Vital signs	Result	Normal range
Pulse	**65/ min**	60-100/ min
BP	**124/67 mmHg**	130/80 mmHg
Temperature	37.5 C	36.6-37.2 C

CBC	Result	Normal range
Hb	**146 g/L**	Male: 135-175 g/L Female: 120-155 g/L
WBC	9 x 10* 9/L	4.5-11 x 10*9/L
Platelets	178 x 10*9/L	140-450 x 10*9/L

Test	Value	Normal values
Creatinine	198 µmol/L	62-115 µmol/L
Urea	16 mmol/L	2.5-6.4 mmol/L
Potassium	3.9 mmol/L	3.5-5.1 mmol/L
Sodium	137 mmol/L	135-145 mmol/L
Bicarbonate	23 mmol/L	22-26 mmol/L

Urine	Result	Normal values
Color	Dark yellow	Amber yellow
Character	clear	clear
PH	6 acidic	4.8-8
Specific gravity	1.021	1.015-1.025
Protein	-	-
Glucose	-	-
RBCs	-	-
Hemoglobin	-	-
Pus cells (WBC)	-	
Amorphus phosphate		
Bacteria	-	-
Granular casts	-	

◄ Approach:

- **Approach to a patient with high creatinine:**
  - **Step one:** determine the baseline of creatinine to specify which type of kidney injury. **Creatinine baseline: 45 µmol/ two days ago**
    - **Acute**
  - **Step two:** determine the etiology (prerenal, renal or postrenal)
    - History and normal specific gravity excludes pre renal causes
    - Renal causes: **ATN:** usually caused by prolonged hypotension, which is not seen in the history **AIN:** usually causes by toxic medications, also not seen in the history. **GN:** no hematuria seen and no proteinuria.
    - Now: check for obstruction using an ultrasound
- **Diagnosis:** AKI
- **Etiology of AKI:** Post renal (obstruction) because of wrong catheter
  - Why? he had his intraurethral **poley catheter** which was changed into a **condom catheter** (inserted outside the urethra) causing obstruction because he has neurogenic bladder due to his paraplegia so he cannot empty his bladder without a foley catheter. so the urine seen is overflow
- **Treatment:** remove the wrong catheter

Cases

◄ Case study 5:

- 76 years old man Known to have: Long standing diabetes and hypertension, ischemic heart disease. presented with acute chest pain and shortness of breath diagnosed to have acute coronary syndrome, underwent cardiac catheterization. Baseline creatinine was 120 (abnormal for 76b y/o man), 12 days later[1] creatinine has increased to 560 with oliguria.
- JVP was normal, skin lesion over lower limbs and absent pedia and posterior tibial arteries, black toes bilateraly
- CVS examination: normal 1st and 2nd heart sounds, no added sounds or murmurs
- Respiratory system: bilateral basal crackles
- Abdominal examination: soft and lax, liver and spleen were not palpable

Vital signs	Result	Normal range
Pulse	**98/ min**	60-100/ min
BP	146/67 mmHg	130/80 mmHg
Temperature	37.5 C	36.6-37.2 C

CBC	Result	Normal range
Hb	**146 g/L**	Male: 135-175 g/L Female: 120-155 g/L
WBC	9 x 10* 9/L	4.5-11 x 10*9/L
Platelets	178 x 10*9/L	140-450 x 10*9/L

Test	Value	Normal values
Creatinine	560µmol/L	62-115 µmol/L
Urea	26 mmol/L	2.5-6.4 mmol/L
Potassium	5.7 mmol/L (hyperkalemia)	3.5-5.1 mmol/L
Sodium	134 mmol/L	135-145 mmol/L
Bicarbonate	13 mmol/L (metabolic acidosis)	22-26 mmol/L

◄ Approach:

- **Approach to a patient with high creatinine:**
  - **Step one:** determine the baseline of creatinine to specify which type of kidney injury. **Baseline creatinine: 120 µmol/L**
    - **Acute on top of chronic**
  - **Step two:** determine the etiology (prerenal, renal or postrenal)
    - Post renal is unlikely (can only be fully excluded when ultrasound is done)
    - Pre renal: no volume depletion and normal BP, pulse and JVP excludes it.
    - Because this happened 12 days post catheterization, it can be caused by
      - Atheroma dislodged by the catheter during the procedure. Which then traveled to the lower limbs leading to livedo reticularis and **cholesterol embolization syndrome** resulting in AKI
      - OR direct damage by contrast received from the cath., it can affect the kidney by 2 ways:
        - **1.** Vasoconstriction resulting in prerenal AKI manifestations (urine Na< 10 and high osmolality
        - **2.** Direct damage to tubular cells resulting in ATN manifestations

      If the rise in creatinine peaked 2 days post cath. it will most likely be contrast induced
- **What is your diagnosis?** AKI on top of chronic
- **What your differential diagnosis?**
  - Atheroembolic disease.
  - Contrast induced AKI.
- **Treatment:** This condition cannot be treated, patient goes to dialysis.

Cases

◄ Case study 6:

- 34 years old man, Presented with lower limb swelling and SOB for 2 week and fatigue. Found to have high Creatinine
- **JVP was normal, bilateral lower limb edema**
- CVS examination: normal 1st and 2nd heart sounds, no added sounds or murmurs
- Respiratory system: lungs are clear to percussion and auscultation
- Abdominal examination: no tenderness, liver and spleen were not palpable

Vital signs	Result	Normal range
Pulse	**88/ min**	60-100/ min
BP	**146/94 mmHg**	130/80 mmHg
Temperature	37.1 C	36.6-37.2 C

CBC	Result	Normal range
Hb	**146 g/L**	Male: 135-175 g/L Female: 120-155 g/L
WBC	9 x 10* 9/L	4.5-11 x 10*9/L
Platelets	178 x 10*9/L	140-450 x 10*9/L

Test	Value	Normal values
Creatinine	245 µmol/L	62-115 µmol/L
Urea	17 mmol/L	2.5-6.4 mmol/L
Potassium	4.9 mmol/L	3.5-5.1 mmol/L
Sodium	139 mmol/L	135-145 mmol/L
Bicarbonate	17 mmol/L	22-26 mmol/L

Urine	Result	Normal values
Color	Yellow	Amber yellow
Character	clear	clear
PH	6 acidic	4.8-8
Specific gravity	1.021	1.015-1.025
Protein	**+++**	-
Glucose	-	-
RBCs	11 /hpf & RBC casts	-
Hemoglobin	-	-
Pus cells (WBC)	1-2 /hpf	
Amorphus phosphate		
Bacteria	-	-
Granular casts	-	

◄ Approach:

- **Approach to a patient with high creatinine:**
  - **Step one:** determine the baseline of creatinine to specify which type of kidney injury. **Baseline creatinine (65 µmol/L)**
    - **Acute**
  - **Step two:** determine the etiology (prerenal, renal or postrenal)
    - Just by looking at the urinalysis you can tell it is **GN** due to the RBCs and proteinuria
- **Diagnosis:** Renal Acute kidney injury: Most likely glomerulonephritis.
- **How would you investigate this patient further?**
  - Blood urea nitrogen and serum creatinine.
  - CBC, peripheral smear, and serology.
  - Urinalysis, 24 hours urine collection for proteins.
  - Urine electrolytes.
  - U/S kidneys.
  - **Serology:** ANA,ANCA, Anti DNA, HBV, HCV, Anti GBM, cryoglobulin, CK, urinary Myoglobulin.
  - **Kidney biopsy**.

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Summary

Acute Kidney Injury	Deterioration of renal function over a period of hours to days, resulting in the failure of the kidney to **excrete** nitrogenous **waste** products and to **maintain** fluid and electrolyte **homeostasis.** It is a common and serious health problem which carry high mortality and morbidity. AKI is amenable to prevention, early detection and treatment. - Oliguria: <400 ml urine output in 24 hours - Anuria: <100 ml urine output in 24 hours
Impact	- increased risk of CKD - increased risk of CV event - increased long-term mortality

AKI Types		
Pre-Renal	Renal	Post Renal
Volume Depletion Decreased cardiac output	Acute Tubular Necrosis (ATN) Acute Interstitial Nephritis (AIN) Acute Glomerulonephritis (GN)	Ureteric obstruction Bladder neck obstruction Urethral obstruction

Renal AKI		
Acute Tubular Necrosis (ATN)	**Acute Interstitial Nephritis (AIN)**	**Acute Glomerulonephritis (GN)**
Causes: Ischemia: Hypotension, sepsis, prolonged prerenal state. Toxic: Heme pigment, Crystals Drugs.	**Causes:** - Drugs - Infection - Systemic disease	**Causes:** Rapidly progressive GN **1. Anti-GBM antibody Immune complex:** **2. Pauci-immune Wegener granulomatosis**
Diagnose by: - History - high (EFNa) >2% - sediment with coarse granular casts	**Diagnose by:** - History of systemic disease known to be associated with AIN. - Skin rash - Eosinophilia - WBC cast (urine) - Eosinophiluria - Renal biopsy	**Clinical features:** - Symptoms and signs of systemic disease - Non specific: lower limb swelling, hematuria, frothy urine - Symptoms and signs of ESRD
Treatment: supportive care: **1. Maintenance of euvolemia** **2. Dialysis**, if necessary. 80% will recover, if initial insult can be reversed	**Treatment:** - d\c offending agent - Conservative -may use steroids	**Treatment:** - general - disease specific: Steroid Immunosuppressive agents Plasmapheresis

Lecture Quiz

Q1: A 53-year-old man with HIV suffers a ruptured aortic aneurysm and is rushed into theatre, he undergoes a successful operation and is recovering on the wards in a stable condition. One day after the operation, he becomes oliguric with mildly elevated urea and creatinine. After 1 week, he becomes polyuric with a GFR of 30. The most likely diagnosis is:

A. Haemolytic–uraemic syndrome
B. Acute tubular necrosis
C. SIADH
D. HIV nephropathy
E. Acute renal failure

Q2: A 16-year-old boy presents with a low-grade fever which started 1 week ago. The patient also reports feeling fatigued and indicates pain in his joints. His parents mention that he has been visiting the toilet more often than usual. A urine dipstick shows trace proteins, while a blood test shows raised eosinophils. The most likely diagnosis is:

A. Acute tubulointerstitial nephritis
B. Renal failure
C. Diabetes mellitus
D. UTI
E. Reactive arthritis

Q3: A 76 year-old man presents to the emergency room. He had influenza and now presents with diffuse muscle pain and weakness. His past medical history is remarkable for osteoarthritis for which he takes ibuprofen, and hypercholesterolemia for which he takes lovastatin. Physical examination reveals blood pressure of 130/90 with no orthostatic change. The only other finding is diffuse muscle tenderness. Laboratory data include

BUN: 30 mg/dL Creatinine: 6 mg/dL K: 6.0 mEq/L Uric acid: 18 mg/dL Ca: 6.5 mg/dL PO4: 7.5 mg/dL

UA: large blood, 2+ protein. Microscopic study shows muddy brown casts and 0 to 2 rbc/hpf (red blood cells/high power field).

Which of the following is the most likely diagnosis?

A. Nonsteroidal anti-inflammatory drug-induced acute kidney injury (AKI)
B. Volume depletIon
C. Rhabdomyolysis-induced acute kidney injury
D. Urinary tRact obstruction
E. Hypertensive nephrosclerosis

Q4: A 65 year old patient with a pulmonary embolism, he is at risk of which type of AKI?

A. Renal
B. Pre renal
C. post renal
D. he is not at risk of AKI

Answers: Q1:B | Q2:A | Q3:C | Q4:B

Answers Explanation File!

GOOD LUCK !

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