NOTES
ACUTE & CHRONIC KIDNEY DISEASE

GENERALLY, WHAT IS IT?

PATHOLOGY & CAUSES

- Decline of kidney function

TYPES

Acute kidney injury (AKI)
- Decline over < three months
- Divided by cause
  - *Prerenal azotemia:* kidney hypoperfusion
  - *Intrarenal azotemia:* injury within kidney
  - *Postrenal azotemia:* obstructed urine outflow distally

Chronic kidney disease (CKD)
- Decline over > three months
- Any etiology causing decreased kidney function

SIGNS & SYMPTOMS

- Electrolyte imbalance (e.g. ↑ K^+, ↓ Na^+, ↓ Ca^{2+})
- Decreased waste elimination (azotemia/uremia)
- Fluid retention

DIAGNOSIS

DIAGNOSTIC IMAGING

Ultrasound, CT scan
- Obstructive renal failure

LAB RESULTS

- Urine electrolytes, osmolality, cellular casts, proteinuria, hematuria
- Acid-base status, electrolytes, protein levels
- Blood urea nitrogen (BUN)-to-creatinine ratio (BUN:Cr)
  - *Prerenal azotemia:* > 20:1
  - *Renal azotemia:* < 15:1
  - *Postrenal azotemia:* > 15:1; over time, < 15:1

TREATMENT

MEDICATIONS

- Correct acid-base status, electrolytes, volemia

OTHER INTERVENTIONS

- Hemodialysis (not used for prerenal azotemia)

CHRONIC KIDNEY DISEASE

osms.it/chronic-kidney-disease

PATHOLOGY & CAUSES

- Gradual decline of kidney function over ≥ three months
- Affects all physiologic roles of kidney
- ↓ Glomerular filtration rate (GFR) → ↓ waste products excretion → build-up of nitrogenous compounds → ↑ BUN, Cr, urea (azotemia/uremia)
  - Inflammation (e.g uremic pericarditis)
  - Interferes with neurotransmitter metabolism → encephalopathy
  - Platelet dysfunction → bleeding (platelet adhesion, aggregation)
  - Excess urea through eccrine glands → crystallizes on skin → uremic frost
- ↓ reabsorption, secretion → impaired electrolyte homeostasis
  - ↑ K^+, ↓ Na^+, ↓ HCO_3^-, ↓ Ca^{2+}
- Impaired hormone secretion
  - ↓ erythropoietin → anemia
  - ↓ GFR → ↑ renin → hypertension
  - ↓ vitamin D activation → ↓ intestinal absorption of Ca^{2+} → hypocalcemia

CAUSES

- Hypertension (most common)
  - ↑ blood pressure → hypertrophy/sclerosis of renal arteries → hypoperfusion, ischemic injury → growth factor secretion by macrophages → mesangial cells regress to mesoangioblasts, secrete extracellular matrix → glomerulosclerosis, loss of function
- Diabetic nephropathy
  - ↑ blood glucose → non-enzymatic glycosylation of efferent arterioles → initial hyperinflation → mesangial cells secrete structural matrix → nodular glomerulosclerosis, loss of function
- Less common
  - Glomerulonephritis (e.g. lupus nephritis); rheumatoid arthritis; HIV nephropathy; long term medication use (e.g. NSAIDs); polycystic kidney disease

RISK FACTORS

- Family history
- Reflux nephropathy
- Other congenital kidney disorders

COMPLICATIONS

- Uremic fibrinous pericarditis, uremic gastroenteritis
- Renal osteodystrophy → increased risk of skeletal fractures; caused by secondary hyperparathyroidism (compensatory parathyroid hormone release due to lack of vitamin D)
- Renovascular hypertension
  - Development/exacerbation of hypertension due to increased RAAS
- Congestive heart failure
- Coma, death by severe encephalopathy

SIGNS & SYMPTOMS

- Less advanced stages usually asymptomatic
- Oliguria
  - Urine output < 400mL in 24 hour
- ↑ fluid volume
  - Peripheral edema
- Azotemia/uremia
- Skin
  - Uremic pruritus, excoriations
- GI tract
  - Ulcerations, bleeding, diarrhea, vomiting
- Encephalopathy
  - Fatigue, somnolence, appetite loss, asterixis, confusion

- ↑ K+ (> 5.5mEq/L)
  - Cardiac arrhythmias
- Anemia
  - Low erythropoietin production by kidneys

DIAGNOSIS

DIAGNOSTIC IMAGING

Ultrasound

- Etiological investigation; polycystic kidney disease (PCKD), renal artery stenosis, hydronephrosis, etc.; decreased kidney volume

LAB RESULTS

- Iron deficiency anemia
- Metabolic acidosis, ↑ PO^{3-}, ↑ K^{+}, ↓ Na^{+}, ↓ HCO_3^{-}, ↓ Ca^{2+}
- Biopsy
  - Glomerulosclerosis/interstitial fibrosis

OTHER DIAGNOSTICS

- Rise of serum Cr over months/years
- Increased blood urea nitrogen:creatinine (BUN:Cr)
- Cr clearance to assess glomerular filtration rate (GFR)
  - *Stage I:* kidney damage with normal/ increased GFR (> 90mL/min/1.73m2)
  - *Stage II:* mild reduction in GFR (60–89mL/min/1.73m2)
  - *Stage IIIa:* moderate reduction in GFR (45–59mL/min/1.73m2)
  - *Stage IIIb:* moderate reduction in GFR (30–44mL/min/1.73m2)
  - *Stage IV:* severe reduction in GFR (15–29mL/min/1.73m2)
  - *Stage V:* end stage kidney failure (GFR < 15mL/min/1.73m2 or dialysis)

TREATMENT

MEDICATIONS

- ACE inhibitors, angiotensin II receptor antagonists (ARBs)

SURGERY

- Kidney transplantation
  - Severe (e.g. Stage V CKI)

OTHER INTERVENTIONS

- Dialysis
  - Severe (e.g. Stage V CKI)
- Hemodialysis
  - Remove excess waste products, fluids via artificial kidney (dialyzer)
- Peritoneal dialysis
  - Remove excess waste products, fluids via peritoneal membrane

POSTRENAL AZOTEMIA

osms.it/postrenal-azotemia

PATHOLOGY & CAUSES

- Acute kidney injury due to obstructed urine outflow distally → ↑ nitrogenous compounds in blood
- Obstruction of urine outflow → reversal of Starling forces → pressure backs up to kidneys, tubules → reduced pressure gradient between arterioles, tubules → ↓ GFR

CAUSES

- Compression
  - Ureters (e.g. intra abdominal tumors); urethra, benign prostatic hyperplasia (BPH)
- Obstruction
  - Ureters; urethra, kidney stones

- Congenital abnormalities
  - Vesicoureteral reflux

COMPLICATIONS

- Hydronephrosis; urinary tract infection (UTI), obstruction, urosepsis

SIGNS & SYMPTOMS

- Normotensive/hypertensive
- Renal colic
  - Acute complete obstruction, dysuria, urgency, overflow incontinence, frequent urination
- Abdominal distention
  - Urinary retention
- Costovertebral angle tenderness
- Pain
  - Bladder distention, secondary infection, stones, masses
- Decreased urine output, hematuria
  - Stones

DIAGNOSIS

DIAGNOSTIC IMAGING

Renal ultrasound

- Detect obstruction; hydronephrosis, stones > 3mm
  - Echogenic foci, acoustic shadowing

CT scan

- Confirmation
- Hyperdense foci; dilation of ureter

LAB RESULTS

- Urinalysis
  - U_{Na+} < 20 mEq/L; over time > 40mEq/L
  - FE_{Na} > 1%; severe: FE_{Na} > 2%
  - U_{oms} > 500mOsm/kg; over time 350mOsm/kg

OTHER DIAGNOSTICS

- Physical exam
  - Palpable bladder
- Digital rectal examination
  - Enlarged prostate

TREATMENT

SURGERY

- Percutaneous nephrostomy, lithotripsy
  - Obstruction by stones

OTHER INTERVENTIONS

- Short term hemodialysis (severe)
- Placement of Foley catheter, ureteral stent/ nephrostomy

PRERENAL AZOTEMIA

osms.it/prerenal-azotemia

PATHOLOGY & CAUSES

- Acute renal injury
  - Kidney hypoperfusion → increased nitrogenous compounds in blood (BUN, Cr)
- Decreased blood flow to kidney → ↓ glomerular filtration rate (GFR), accumulation of waste products (BUN, Cr) in blood → azotemia
- ↓ GFR → renin–angiotensin–aldosterone system (RAAS) activation → aldosterone secretion → Na+, water retention → urea follows Na+ → ↑ BUN:Cr (> 20:1)

CAUSES

- Absolute fluid loss
  - Burns, dehydration, long term vomiting, diarrhea, hemorrhage
- Relative fluid loss
  - Congestive heart failure, distributive shock
- Renal artery stenosis/embolus
- Liver failure
  - Portal hypertension → systemic, splanchnic vasodilation → ↓ effective blood volume, ↑ sequestration in peritoneal cavity (ascites) → relative hypovolemia → ↓ renal perfusion

RISK FACTORS

- Gastrointestinal (GI) tract disorders (e.g. diarrhea, vomiting)
- Liver disease
- Congestive heart failure

SIGNS & SYMPTOMS

- *Oliguria:* urine output < 400mL in 24 hours
- *Azotemia:* confusion, lethargy, asterixis, appetite loss, nausea, bleeding (platelet dysfunction), uremic frost
- *Dehydration:* dry mucous membranes, skin turgor loss, thirst, xerostomia (dry mouth), tachycardia, orthostatic hypotension
- *Congestive heart failure:* jugular vein distention, edema
- *Underlying liver failure:* ascites

DIAGNOSIS

DIAGNOSTIC IMAGING

Doppler renal ultrasound

- Renal artery stenosis/embolus

LAB RESULTS

- Absolute fluid loss
  - ↑ Na^+, ↑ Ca^{2+}, ↑ hematocrit, ↑ HCO_3, ↑ protein/albumin
- Relative fluid loss
  - ↓ Na^+, ↓ protein/albumin
- Urine sodium (U_{Na+}) < 20mEq/L
- Fraction of sodium excreted to sodium filtered (FE_{Na}) < 1%
- Urine osmolality (U_{oms}) > 500mOsm/kg

OTHER DIAGNOSTICS

- BUN:Cr > 20:1

TREATMENT

MEDICATIONS

- Diuretics, angiotensin-converting enzyme (ACE) inhibitors, beta blockers, nitrates, positive inotropic agents
  - Congestive heart failure

OTHER INTERVENTIONS

- Correct fluid, electrolyte imbalances with IV fluids
  - *Crystalloid solutions:* isotonic solutions containing electrolytes, small organic molecules (e.g. isotonic saline, Ringer's

lactate); most common
    - *Colloid solutions:* hypertonic solutions containing larger molecules; albumin, hyperoncotic starch (e.g. glucose, dextrose)
    - *Blood transfusion:* in case of hemorrhage

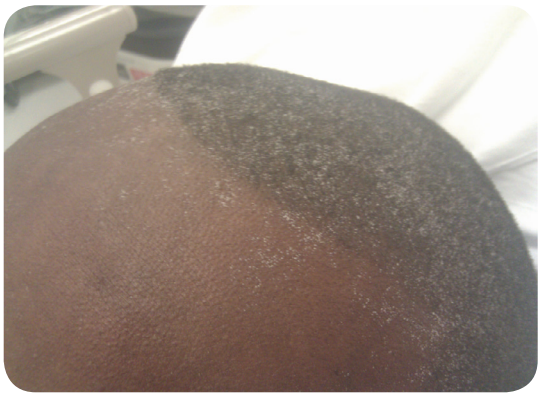

Figure 106.1 The clinical appearance of uremic frost in an individual with azotemia.

RENAL AZOTEMIA

osms.it/renal-azotemia

PATHOLOGY & CAUSES

- Acute renal injury caused by problem within kidney → increased nitrogenous compounds in blood
- Kidney injury → ↓ GFR → accumulation of waste products in blood → azotemia

CAUSES

Glomerular injury

- Glomerulonephritis
    - Inflammation of glomeruli (e.g. poststreptococcal glomerulonephritis, Goodpasture's syndrome, Wegener's granulomatosis, IgA nephropathy)
    - Deposition of immune complexes on glomerular basement membrane → activation of complement system → chemoattraction of macrophages, neutrophils → mediator release → inflammation, podocyte damage → protein, blood cell leakage → reduces pressure gradient between arterioles, tubules → ↓ GFR, oliguria

Tubular injury

- *Acute tubular necrosis:* damage to tubular epithelial cells; shedding of tubular cells, granular casts in urine
    - *Ischemic tubular necrosis:* caused by prerenal issues (hypoperfusion due to absolute, relative fluid loss)
    - *Nephrotoxic tubular necrosis:* caused by nephrotoxins, like organic solvents (carbon tetrachloride), heavy metal poisoning (lead, mercury), ethylene glycol, radiocontrast agents, certain medications (aminoglycosides)
- Shedded tubular cells, granular casts obstruct tubule → ↑ tubular pressure → reduces pressure gradient between arterioles, tubules → ↓ GFR → oliguria

Interstitial injury

- Acute interstitial nephritis
    - Caused by Type I, IV hypersensitivity due to nonsteroidal anti-inflammatory drugs (NSAIDs)/penicillin/diuretics
    - Inflammation of interstitium → renal papillary necrosis → hematuria
- Bilateral pyelonephritis

Glomerular endotheliopathy

- Thrombotic microangiopathy, hyaline arteriolosclerosis, scleroderma

RISK FACTORS

- Family history of congenital/systemic diseases (e.g. diabetes, hypertension, systemic lupus erythematosus, hepatitis B, C)

SIGNS & SYMPTOMS

- Oliguria, hematuria, flank pain, livedo reticularis (lace-like purplish skin discoloration)
- Fluid build-up
  - Hypertension, hypertensive retinopathy, edema
- Azotemia
  - Confusion, lethargy, asterixis, loss of appetite, nausea, bleeding (platelet dysfunction)
- Hypersensitivity
  - Rash, fever, joint swelling/tenderness

DIAGNOSIS

LAB RESULTS

- U_{Na+} > 40mEq/L
- FE_{Na} < 2%
- U_{oms} > 350mOsm/kg
- Erythrocyte, leukocyte, epithelial casts: glomerulonephritis
- Pigmented muddy brown granular/tubular epithelial cells cylinders: acute tubular necrosis

OTHER DIAGNOSTICS

- BUN:Cr < 15:1
- Interstitial nephritis
  - Hypersensitivity, acute interstitial nephritis
  - ↑ *IgE*: Type I
  - *Skin test*: T-cell mediated Type IV
  - Eosinophilia

TREATMENT

MEDICATIONS

- Glomerulonephritis; treat according to etiology (e.g. corticosteroids)
- Pyelonephritis
  - Antibiotics

OTHER INTERVENTIONS

- Avoid nephrotoxins/allergens
- Glomerulonephritis; treat according to etiology (e.g. plasmapheresis)
- Hemodialysis

KEY DIAGNOSTIC FINDINGS IN AZOTEMIA

	PRERENAL	INTRARENAL	POSTRENAL
BUN:Cr	> 20:1	< 15:1	< 20:1
U_{Na+}	< 20 mEq/L	> 40 mEq/L	< 20 mEq/L
FE_{Na}	< 1%	< 2%	> 1%
U_{oms}	> 500 mOsm/kg	> 350 mOsm/kg	> 500 mOsm/kg