**General**

Renal calculi are crystalline mineral deposits that form in the kidney. They develop from microscopic crystals in the loop of Henle, the distal tubule, or the collecting duct, and they can enlarge to form visible fragments. The process of stone formation depends on urinary volume; concentrations of calcium, phosphate, oxalate, sodium, and uric acid ions; concentrations of natural calculus inhibitors (e.g., citrate, magnesium, Tamm-Horsfall mucoproteins, bikunin); and urinary pH. Many calculi have a mixed composition, with one type of crystal becoming a nidus for heterogeneous crystallization

**Epidemiology**

* 5 percent in the general population
* Annual incidence of 1 percent
* Male to female ratio = 4:1, after 6th decade, ratio = 1.5:1
* Symptomatic nephrolithiasis incidence increases in summer months
* After passage of a calcium stone, the likelihood of forming a second stone is approximately 15 percent at one year, 35 to 40 percent at five years, and 50 percent at 10 years, with men being more likely to recur than women

**Risk factors**

**Calcium oxalate Calculi** (>50% in both children and adults)

* Hypercalciuria (>250mg/24H)
  + Most common is idiopathic**;** primary hyperparathyroidism via increased intestinal absorption of Ca and increased bone demineralization
* Hyperoxaluria (>45mg/24H)
  + Enteric cause from malabsorption (ex: Crohn’s); primary hyperoxaluria: metabolic error with increased oxalate formation and urinary excretion
* Hyperuricosuria (>800mg/24H): increased uric acid promotes calcium oxalate crystallization by forming a template for nucleation
* Hypocitraturia (<450mg/24H): idiopathic; renal tubular acidosis (RTA) types 1,2,&4

**Calcium Phosphate Calculi** (25-30% in children, 8-18% in adults)

* RTA via alkalization of urine, hypercalciuria and hypocitrateuria
* Primary hyperparathyroidism creates persistent hypercalciuria
* Excessive alkalinization promtes calcium phosphate supersaturation and loss of citrate
* Sarcoidosis

**Uric Acid Calculi** (2-4% in children, 9-17% in adults)

* Low urinary pH (<5.5)
* Gout promotes hyperuricosuria
* Insulin resistance: Ammonia mishandling; alters pH of urine
* End-illeostomies promote low urine volume; acidic urine depletes available citrate; hyperoxaluria
* Excess animal protein consumption creates acidic urine, depletes citrate, promotes hyperuricosuria

**Struvite Calculi** (consist of magnesium, ammonium, calcium phosphate; leading cause of staghorn calculi; 7-13% in children, 2-4% in adults)

* Neurogenic bladder
* Foreign body in urinary tract
* Recurrent UTIs with urea-splitting organisms (proteus, ureaplasma, klebsiella), which alkalinize urine and produce ammonium

**Cystine Calculi** (5-8% in children, 1% in adults)

* Cystinuria: autosomal recessive disorder where the proximal tubular and jejunal transport of dibasic amino acids cysteine, lysine, arginine, and ornithine are defective and result in excessive loss via the urine

**Other risk factors**

* Excess dietary sodium: Promotes hypercalciuria
* Low urine volume: Allows stone constituents to supersaturate
* Obesity, rapid weight loss, laxatives
* Prolonged immobilization: Bone turnover creates hypercalciuria
* Medications: Uricosurics, diuretics, vitamin C&D, antacids (esp phosphorus binding agents), acetazolamide, CCB, triamterene, theophylline, protease inhibitors, sulfonamides

**Symptoms**

* Colic: sudden, severe, paroxysmal pain produced from peristaltic smooth muscle contractions of ureteral walls against a calculus (usually asymptomatic until they reach ureters)
  + Originates in flank and radiates to groin, can also be referred to labia or testes
* Other possible symptoms include fevers, chills, nausea, vomiting, hematuria, increase in frequency of urination, increase in urgency of urination

**Differential Diagnosis**

* UTI, pyelonephritis
* Abdominal: SBO, appendicitis, cholecystitis, diverticulitis, ischemic bowel, AAA
* Pelvic inflammatory disease, Ectopic pregnancy
* Ovarian or testicular pathology
* Musculoskeletal inflammation or spasm
* Malignancy
* Factitious (drug seeking)

**Diagnostic Studies**

* Physical exam:
  + General impression: often patient is constantly moving, attempting to lessen pain
  + Hypo active bowel sounds, +CVA tenderness
* Labs: Electrolytes, Ca, Phosphate, uric acid, CBC, PTH
* UA: hematuria (absence does not exclude stone), pH (<5 = uric acid or cysteine stone, >7.5 = struvite stone)
* Urine culture
* Abdominal x-ray: Sensitivity 58-62%; calcareous stones usually are visible on radiographic imaging, whereas noncalcareous stones (i.e., uric acid, cystine, struvite calculi) often are radiolucent or poorly visualized on plain film radiography; valuable when combined with US or IVP
* Renal Ultrasound: 44-57% sensitivity, but can miss >30% of acute renal stone obstructions when patient not hydrated for study; study of choice in pregnant women and children
* Non-contrast helical CT: 88-100% sensitivity; current gold standard as more sensitive than ultrasound and therefore more likely to visualize a stone. Downside is radiation exposure, and cumulative doses of radiation may be high in patients who have recurrent nephrolithiasis and need frequent imaging; looking for a "rim" or “halo” sign on CT scanning due to circumferential edema from ureteral lithiasis
* Excretory urography (IVP): prior gold standard, but requires IV contrast and time consuming; gives info on location, size, and degree of obstruction; contraindicated in renal insufficiency, dehydration, pregnancy, prior contrast rxn

**Treatment and follow-up**

* Pain control with NSAIDs and/or opioids
* Stones <5mm pass spontaneously in 90 percent of patients
* Straining urine — Patients should be instructed to strain their urine for several days and bring in any stone that passes for analysis to better plan preventive therapy
* Medications can help facilitating stone passage, including antispasmodic agents, calcium channel blockers, and alpha blockers
* Referral to a urologist is warranted when more than one stone is present, symptoms worsen with fever, renal function is impaired, stone passage is prolonged, hydronephrosis is diagnosed based on imaging findings, the patient is pregnant, or the stone is larger than 5 mm in diameter as measured using computed tomography or ultrasound
* Current options for therapy of stones that do not pass include
  + shock wave lithotripsy (SWL): 1st line management; treatment of choice in 75 percent of patients and works best for stones in the renal pelvis and upper ureter; approximately 1/3 have transient mild fever, with obstruction by the stone fragments or urinary tract infection occurring in less than 10 percent of cases
  + ureteroscopic lithotripsy with electrohydraulic or laser probes: 1st line management; yields higher stone-free rates, but with an increased incidence of complications over shock wave lithotripsy
  + percutaneous nephrolithotomy or laparoscopic stone removal
* 24 hour urine collections: need at least 2, possibly a 3rd if great variability between the 2; obtain in the outpatient setting when the patient is on his or her usual diet; wait at least one to three months after a stone event to obtain the collections and make sure that the urine is not infected or the collecting system obstructed

**Prevention**

* Increased fluid intake (approx. 2L daily)
* Dietary recommendations tailored to the individual's habits and urine composition may be beneficial
* Patients with calcium stones who cannot be solely managed with dietary modifications can be treated with a thiazide diuretic and low sodium diet for hypercalciuria, allopurinol for hyperuricosuria, and potassium citrate for hypocitraturia.
* Patients with uric acid stones can be treated with potassium citrate to alkalinize the urine and occasionally allopurinol (for patients with severe hyperuricosuria).
* Patients with cystine stones can be treated with a high fluid intake, urinary alkalinization, and drugs such as tiopronin.
* Struvite stones typically require complete stone removal with percutaneous nephrolithotomy and aggressive prevention and treatment of future urinary tract infections