Kidney Stones (Nephrolithiasis): Classification, Symptoms, and Treatment

See online here

Nephrolithiasis is a clinical condition characterized by the presence of stones in the kidney. Calcium oxalate stones are the most common stones. Clinical presentation is with acute flank pain. Non-contrast CT is the investigation of choice in nephrolithiasis and can diagnose all types of stones. Management depends on the location and size of the stone. Smaller stones have a greater chance to pass spontaneously, while stones larger than 5 mm need surgical management with percutaneous nephrolithotomy, extracorporeal lithotripsy, or open surgery.

Definition

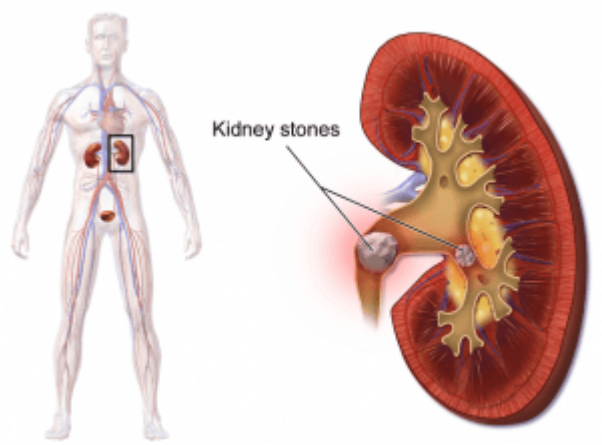

Image: Kidney stones. By: BruceBlaus. License: CC BY 3.0

Nephrolithiasis, also called kidney stones or renal calculus, is a condition in which stones are formed within the nephrons (see image). It occurs due to supersaturation and crystallization of inorganic and organic phosphates and acids.

Epidemiology

Nephrolithiasis is one of the most common urological disorders, with roughly 2 million patients in the United States presenting annually on an outpatient basis with the condition. It has a prevalence of 12% in males and 7% in females. The recurrence rate is estimated to be 52% at 10 years after the first episode.

Classification

Calcium Stones

Calcium stones form a major part of all stones. There are two types of calcium stones:

- Calcium oxalate stones (most common, at 70%–80%)
- Calcium phosphate stones (approximately 15%)

Magnesium Ammonium Phosphate Stones (Struvite Stones)

Struvite stones, or triple phosphate stones, are commonly associated with urinary tract infections by urease-producing bacteria (*Proteus*). They are more common in females than in males, as there is an increased predisposition of urinary tract infection in females. When a stone is large and branched, filling all or part of the renal pelvis, it is called a **staghorn calculus** (see images).

Image: Removed struvite stone weighing 123 grams. By: openi. License: CC BY 3.0

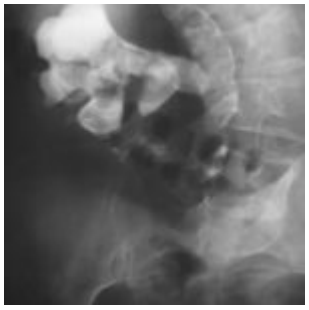

Image: Staghorn kidney stone. By: Nevit Dilmen. License: CC BY-SA 3.0

Uric Acid Stones

Uric acid stones are characteristically seen in patients with **hyperuricemia** due to either excessive uric acid production or under-secretion.

Cystine Stones

Cystine stones are seen in patients with a defective amino acid transporter in the proximal tubule with decreased reabsorption of cystine. They lead to an increased concentration of cystine in the urine (cystinuria), resulting in the formation of pathognomonic **hexagonal-shaped** stones.

Pathophysiology and Risk Factors

Supersaturation and **crystallization** are the two primary factors responsible for stone formation. Multiple risk factors promote nephrolithiasis, including urinary, dietary, and non-dietary factors.

Urinary Factors

Urine pH: This affects the likelihood of kidney stone formation. Acidic urine favors uric acid precipitation, while an alkaline urine (as may be seen in urinary tract infections and renal tubular acidosis) promotes calcium phosphate stone formation.

Hypercalciuria: Increased urinary calcium excretion promotes nephrolithiasis. Hypercalciuria may be due to an increase in intestinal absorption, bone resorption, or renal loss.

Hyperoxaluria: Increased urinary oxalate excretion promotes nephrolithiasis by binding to calcium and forming insoluble calcium oxalate stones.

Hypocitraturia: An under-secretion of urinary stone inhibitors (eg, citrate) promotes nephrolithiasis. The citrate usually combines with calcium-forming soluble complexes, making calcium unavailable to bind to oxalate.

Low urine volume: Decreased urinary volume increases the risk of nephrolithiasis due to supersaturation and precipitation of crystals.

Dietary Factors

Calcium: A higher-calcium dietary intake is associated with a lower incidence of kidney stones. Normally, intestinal calcium binds to oxalates and prevents their absorption into the circulation. Decreased calcium leads to an increased absorption of oxalates, which further predisposes the patient to calcium oxalate stones.

Oxalate: A higher oxalate intake increases urinary oxalate excretion and thus increases the risk of nephrolithiasis.

Protein: Higher animal protein is related to higher urine calcium excretion and lower urine citrate excretion, both of which increase the likelihood of stone formation.

Decreased fluid intake increases the risk of nephrolithiasis. It is recommended that individuals drink at least 8–10 glasses of water per day.

Nondietary Factors

- **Family history:** A positive family history of kidney stones increases the risk of stone formation by 2.5 times.
- **Systemic disorders:** Nephrolithiasis is associated with multiple systemic disorders, including primary hyperparathyroidism, renal tubular acidosis, Crohn’s disease, and gout.
- **Environmental factors:** Higher temperatures and increased fluid loss in sweating without adequate fluid intake promote stone formation due to lower urine volume.

Clinical Features

Abdominal pain is the presenting feature of nephrolithiasis. The pain can be moderate to severe in intensity and **colicky and paroxysmal** in nature. It is often associated with nausea and vomiting. The location of pain depends on the site of obstruction. The presence of flank pain **radiating to the groin** is due to the presence of a stone in the **lower ureter**, while the presence of constant flank pain indicates the presence of a stone at the **upper ureter** or at **the ureteropelvic junction**. Patients are usually restless and agitated.

Diagnosis and Laboratory Investigations

Urine Examination

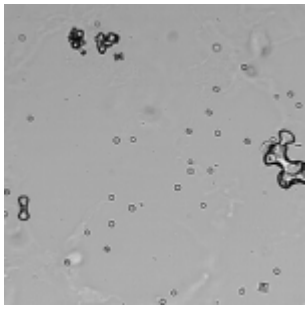

Image: Calcium oxalate crystals—envelope- and dumbbell-shaped crystals in the urine. By: Doruk Salancı. License: CC BY-SA 3.0

Microscopic urine examination may show **characteristic crystals** that form as a result of supersaturation of the inorganic salts present in the urine.

- **Calcium stones:** envelope- or dumbbell-shaped oxalate crystals (see image)
- **Struvite stones: "**coffin-lid" crystals (see image)
- **Uric acid stones:** rhomboid or rosette-shaped stones

- Image: Coffin-lid crystals seen in struvite stones. By: Joel Mills. License: CC BY-SA 3.0

Cystine stones: hexagonal stones

Urine dipstick test helps show etiologic differentiations by checking pH, erythrocytes, leukocytes, bacteria, and protein. Urine **cyanide-nitroprusside test** is positive for **cystinuria.**

Radiological Investigations

Plain X-ray: Most renal stones are radio-opaque and can be seen on plain abdominal X-ray. The notable exception is uric acid stones, which are radiolucent.

Ultrasound: This can help identify renal stones and accompanying **hydronephrosis.**

Computed tomography (CT) scan: A non-contrast CT scan is the **investigation of choice** in the diagnosis of the nephrolithiasis. It helps diagnose all kind of stones (including radiolucent uric acid stones), along with their accurate size and location (see image).

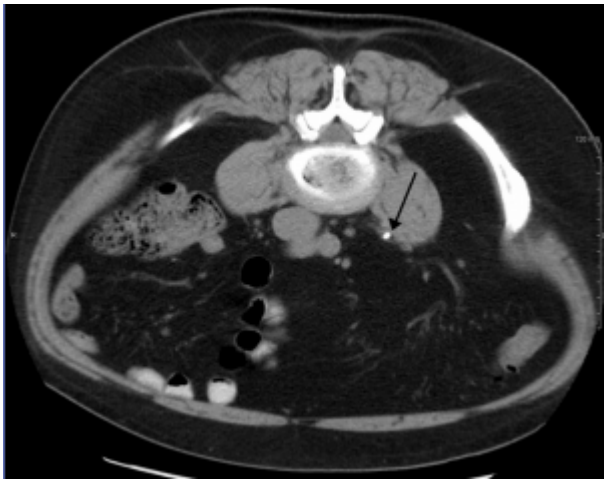

Image: 3 mm stone in the ureter. By: James Heilman, MD.
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Stone Analysis

Urine analysis of kidney stones is recommended to determine stone type and address risk factors accordingly.

Treatment

Acute pain management involves the administration of **nonsteroidal anti-inflammatory drugs** and **opioids**. Anti-emetic drugs are also given.

The specific treatment depends on the extent, nature, and location of the stone. It usually involves a combined medical and surgical approach.

Generally, **smaller stones (< 5 mm)** have an increased chance of responding to medical treatment. Most of these stones will pass spontaneously in the urine, whereas stones **> 5 mm** are less likely to pass on their own.

Medical Therapy

Medical therapy involves a wait-and-watch approach, increased fluid intake, and urine alkalinization. **Oral alpha-adrenergic blockers** can be administered if the stone is small and located in the lower ureter. These drugs decrease the tone of the urethral muscle and facilitate the smooth passage of small stones.

In uric acid stones, medical treatment also includes the administration of **xanthine oxidase inhibitors,** while in cysteine stones, a low-methionine diet is advised.

Surgical Management

Extracorporeal shock wave lithotripsy is a non-invasive method in which targeted high-frequency ultrasound shock waves are used from outside of the body to break a kidney stone into small fragments. These fragments then pass easily through the urinary tract.

Percutaneous nephrolithotomy is a minimally invasive surgery in which kidney stones are removed by making a small incision through the skin. This method is used for stones that are easily approached, located near the pelvic region, and > 2 cm in size.

Open Surgery

Administration of antibiotics is required to treat acute infection and maintain the sterile tract (see table below):

- Hydration (> 2 L per 24 hours) and pain management (opiates)
- Anti-spasmodics (calcium channel blockers, alpha antagonists) may hasten stone passage by 5–7 days
  - No role for corticosteroids
- Antibiotics are indicated in cases of concomitant UTI
- Prevention of stones:
  - Calcium stones:
    - Reduced consumption of salt, animal protein, oxalate-rich foods, and supplemental vitamin C
    - Thiazide diuretics should be considered
  - Uric acid stones: Allopurinol
  - Urine alkalinization or acidification, depending on urinary pH and stone composition

Solitary Stone (< 5 mm; non-pregnant patient)

Prognosis

Most kidney stones pass spontaneously. There is an increased chance of recurrence in patients with nephrolithiasis. Increased fluid intake along with metabolic evaluation is recommended in these patients.

Hospitalization is required in conditions where an obstruction due to kidney stones is associated with urinary tract infection. Emergent surgical drainage is required in the presence of urosepsis and pyelonephritis.

References

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Notes