# Objectives:

1. Give a differential diagnosis for acute flank pain in an adult. Discuss how to differentiate the possible causes of acute flank pain using history, physical exam, laboratory tests and radiologic studies.

2. Name four different kinds of renal calculi and the factors that predispose some individuals to form stones.

3. Discuss the acute management of a patient with renal colic due to an obstructing ureteral stone.

4. Describe the mechanism whereby extracorporeal shock wave lithotripsy (ESWL) is able to fragment stones.





# Intoduction:

Stones may be formed or become clinically evident at any point along the urinary tract. For the purposes of this discussion, only renal and ureteric stones will be considered. Urolithiasis is a common condition with a lifetime risk (for North American males) of **1 in 8**. The male: female ratio is **3: 1**. There are numerous types of stones but the pathophysiology for all types is the same: a) supersaturation of the urine with stone-forming constituents (i.e.: calcium, oxalate, phosphate, uric acid, cystine, etc…), b) presence of chemical or physical stimuli that promote stone formation, c) inadequate amount of compounds in urine that inhibit stone formation (e.g. magnesium, citrate). The presence of urinary stasis, foreign bodies, anatomic abnormalities, extremes of urine pH and/or urinary tract infections (e.g. with urea splitting microorganisms) may accelerate or promote stone formation.

## Signs and Symptoms:

Patients may present dramatically with renal colic; a paroxysmal, incapacitating flank pain that is associated with nausea and vomiting, diaphoresis, tachycardia, tachypnia and often radiates to the scrotum/labia. The presence of renal colic indicates acute obstruction of the ureter. There are 3 common sites of obstruction at the areas of tightest stricture in the urinary system: 1. ureteropelvic junction, 2. crossing of iliac artery (midureter), 3. ureterovesical junction. If the stone is in the distal or intramural ureter, the patient may describe considerable urinary frequency or urgency. Patients with renal colic often move around a lot trying to find a comfortable position in contrast to conditions with peritonitis where the patients tend to lie still. Patients can also experience non-colicky flank pain as result of renal capsular distention due to ureteric obstruction and upstream distention. Renal colic due to a ureteral stone is associated with hematuria (microscopic or gross) in 85% of cases. The physical examination and basic laboratory tests should be conducted in order to exclude other conditions that might mimic stone disease (see below). **Some of these diagnostic possibilities are life threatening so a prompt and accurate diagnosis of acute flank pain is mandatory.**

## Differential Diagnosis of Acute Flank Pain:

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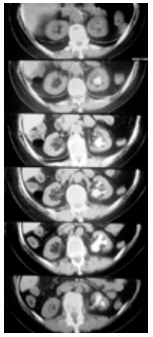
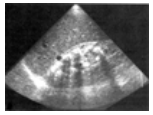
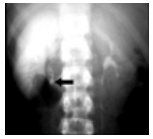
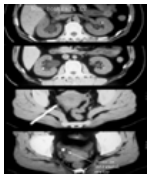
|---|---|
| Abdominal aortic dissection | Acute pancreatitis |
| Abdominal aortic aneurysm rupture | Renal abscess |
| Cholecystitis | Pyelonephritis |
| Biliary colic | Acute glomerulonephritis |
| Appendicitis | Renal vein thrombosis |
| Diverticulitis | Renal infarct |
| Inflammatory bowel disease | Ectopic pregnancy |
| Duodenal ulcer | Pelvic inflammatory disease |
| Viral gastroenteritis | Fitz-Hugh-Curtis syndrome |
| Splenic infarct | Torsion/rupture of ovarian cyst |
| Acute lumbar disc herniation/rupture | Endometriosis |
| Herpes zoster | |

# Imaging:

Patients with signs or symptoms of urolithiasis need imaging studies in order to confirm the diagnosis and plan any future management. The abdominal flat plate (a.k.a. **KUB** x-ray which stands for "kidneys, ureters, and bladder") has been a very important "initial" study since approximately 85% of kidney stones are sufficiently calcified to be seen on plain x-rays. A KUB lacks functional information regarding the degree of obstruction and small stones may not be seen. In many emergency rooms, patients will undergo a **non-contrast CT scan** (often called CT-KUB) which is a very sensitive test for demonstrating kidney stones including uric acid stones (uric acid stones are radiolucent on plain x-rays). Using a CT-KUB, the degree of obstruction is estimated by the presence and severity of hydronephrosis proximal to the stone. CT scan is also very useful to rule out any other conditions that might mimic renal colic such as abdominal aortic aneurysm rupture. Another useful test is an **IVP** which gives functional information regarding the degree of obstruction but which requires the use of intravenous contrast (expensive, possible allergic reactions and nephrotoxicity).

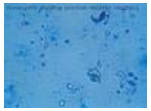







# Lab Tests:

Laboratory tests that should be performed on a patient with suspected or confirmed urolithiasis include a WBC count, serum creatinine and a urinalysis. Important information to gain from the urinalysis includes urine pH and presence of any crystals which may indicate the composition of the stones (e.g. uric acid stones present with acidic urine and struvite stones generally form in alkaline urine). Urine culture should be performed as the presence or absence of bacteria effects therapy.



# Indications for Immediate Referral:

1. Signs and symptoms of a possible UTI (e.g. fever, pyuria, bacteriuria or leukocytosis) in a patient with an obstructed ureter – potentially life threatening

2. Patients with insulin dependant diabetes, as they are at increased risk for complications related to ureteric obstruction (e.g. papillary necrosis, emphysematous pyelonephritis)

3. Patients with a solitary kidney or pre-existing renal impairment

4. Patients with significant co-morbid conditions (e.g. pregnant, CHF, anticoagulent medication, etc…)





# Management:

**Medical:** In cases of uncomplicated ureteral stones, spontaneous passage of the stone is most desirable. Distal ureteral stones are likely to pass spontaneously. As well, a stone **4 mm** or less in diameter has a **90%** chance of spontaneous passage although it may take several days (or weeks) and cause considerable discomfort in the process. Stones between **5 mm** and **7 mm** in diameter have a 50% chance of spontaneous passage and stones **8 mm** or larger are unlikely **(< 20%)** to pass without intervention. Medical therapy consists of hydration, straining the urine and analgesia. Most commonly prescribed medications are codeine, morphine, diclofenac (Voltaren) or ketorolac (Toradol). The NSAIDs are effective for renal colic because they interfere with the reflex increase in renal blood flow seen in acute ureteral obstruction (therefore minimizing the increase in pressure in the collecting system on the obstructed side). The best strainer to use is a pet fish net (from any pet store) because of the convenient handle and small size. Most patients can be discharged from the emergency room to try and pass the stone at home. Indications for admission to hospital or immediate referral to a urologist are discussed above.

**Surgical:** Immediate relief of obstruction may be accomplished in two ways; retrograde insertion of a **ureteric stent** (placed by a urologist via cystoscope and retrograde pyelography) or **percutaneous nephrostomy** (placed by a radiologist with ultrasound guidance). Ureteric stones that fail to pass spontaneously are treated with **extracorporeal shock wavelithotripsy (ESWL), ureteroscopy with direct extraction or ureteroscopy with lithotripsy under direct vision.** ESWL is the least invasive treatment and most commonly used for renal and ureteric stones less than 20 mm in diameter. The patient, under varying degrees of sedation, is placed on a table and the stone is localized with x-rays. The shockhead is brought into contact with the skin so that the focal point of the shockwaves is directed at the stone. The release of energy as the shockwaves hit the stone causes the stone to fragment and repeated shockwaves will reduce the stone to small particles, which are passed in the urine. Stones larger than **20 mm** in diameter may be fragmented by ESWL but the stone burden is so large that it is unlikely all the fragments will pass. Larger stones are better treated with percutaneous nephrolithotripsy (see later). Ureteroscopy is slightly more invasive but is more widely available than ESWL. The technique requires either a spinal or general anaesthetic but is often done as an outpatient. A rigid or flexible ureteroscope is passed per urethra into the bladder and up the ureter under direct vision. Using a variety of miniaturized instruments, the stone may be grasped with a basket/grasper and removed under direct vision or fragmented in-situ. Open surgery is

a last resort (called ureterolithotomy) and is rarely required.





## Types of Stones:

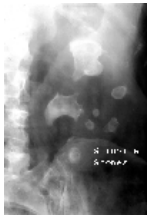
**Calcium oxalate** stones are the most common form of kidney stone and are often formed due to hyperoxaluria brought on by a diet rich in oxalate. A common myth is that dietary calcium should be reduced in calcium stone formers. In fact, dietary calcium binds dietary oxalate and prevents the absorption of oxalate so a reduction of dietary calcium often causes a paradoxical increase in stone formation (by increasing intestinal absorption of oxalate). Common foods high in oxalate include chocolate, nuts, tea, strawberries, peanut butter and cabbage. Other metabolic abnormalities associated with calcium oxalate stone formation include hypocitraturia (urinary citrate is an inhibitor of calcium stone formation) and hypercalciuria. Hypercalciuria may be inherited in an autosomal dominant fashion in some families or it may be sporadic. The underlying mechanism is increased intestinal absorption of dietary calcium. Unfortunately, reducing the amount of dietary calcium has little effect on the amount of calcium absorbed. Diets high in sodium and meat proteins also result in hypercalciuria. No specific dietary advice should be given to a patient until a metabolic evaluation is done, including 24 hour urine collections for calcium, oxalate, citrate, uric acid, phosphate and sodium.

**Calcium phosphate** stones are second in prevalence after calcium oxalate stones and are seen in specific metabolic conditions; distal renal tubular acidosis, hyperparathyroidism and other hypercalcemic conditions like malignancy or sarcoid. These conditions are easy to identify radiographically as patients usually have multiple stones located throughout both kidneys. Medical treatment centers on correction of the metabolic abnormalities. Pre-existing stones cannot be cleared medically and require some intervention (i.e.: ESWL) to clear them.

**Uric acid** stones are seen in patients with persistently acidic urine and in patients with persistent hyperuricosuria. Urine will be persistently acidic in patients with chronic diarrhea (i.e.: inflammatory bowel disease) or low urine output (living in a hot climate, inadequate fluid intake). Hyperuricosuria is seen primarily in men and is due to excess dietary purine intake (meat proteins – which also increase urinary calcium; see above) but may be due to increased endogenous production of uric acid (lymphoma, leukemia and other malignancies; particularly at the time of chemotherapy administration). Uric acid stones are notable for the fact that they are radiolucent on plain x-rays (they are visible on CT scan) and appear as “filling defects” on contrast studies of the urinary tract. They are also unique compared to other types of stones since they may be dissolved by alkalinizing the urine. Medical treatment for non-obstructing stones is increased fluid intake and urinary alkalinization with oral sodium bicarbonate or oral potassium citrate.

**Cystine** stones are formed in patients with cystinuria; an autosomal recessive disorder where the renal tubular reabsorption of cystine, ornithine, lysine and arginine is impaired or absent. These amino acids are excreted in the urine at high concentrations. There is no disease associated with the loss of the amino acids but, unfortunately, cystine is highly insoluble in urine (the other amino acids are soluble) therefore, recurrent stone formation results. Medical treatment involves increased fluid intake, alkalinization of the urine (increases the solubility of cystine slightly) and oral penicillamine (which binds to cystine in the urine and increases the solubility).

**Struvite** stones (a.k.a. infection stones or triple phosphate stones) are composed of magnesium phosphate, ammonium phosphate and calcium phosphate and are notable for the tendency to form large staghorn stones. Staghorn stones may be formed by uric acid or cystine on occasion but the great majority of staghorn calculi are struvite. Struvite stones will only form in a highly alkaline urine (more alkaline than the kidneys are capable of creating) which is seen when the urine is infected with a urease producing bacteria. Bacterial urease will hydrolyze urea to free ammonia and carbon dioxide raising the urine pH to 8.0 - 9.0. The most commonly isolated bacteria in patients with staghorn stones are proteus, providencia, klebsiella, pseudomonas and staph aureus. E. coli do not produce urease but may be isolated as a superinfection. Struvite stones are known to harbour bacteria within the matrix of the stone and the penetration of antibiotics into the stone is not sufficient to cure the infection. Any treatment that does not completely remove all stone fragments invariably results in a recurrence of the infection and re-growth of the stone. These large stones are often discovered during the evaluation of recurrent UTIs, gross hematuria or renal impairment. Treatment is often with percutaneous nephrolithotripsy where a 30 F diameter “stone tract” is created directly from the flank into the collecting system of the kidney and a nephroscope is inserted to fragment the stone under direct vision. The fragments are irrigated out of the collecting system (through the nephroscope) during the procedure. ESWL is reserved for any residual fragments after the patient has recovered. Nephrectomy may be considered if the staghorn stone is present in a poorly functioning kidney.



Other types of stones include triamterene (radiolucent) and indinavir (radiolucent) stones which are crystallizations of the drug within the urinary collecting system. Fictitious stones (i.e.: small rocks) are sometimes brought in by patients seeking narcotics. Other drugs which can predispose to stones include:

- high doses of vitamin C (metabolized to oxalate)
- high doses of vitamin D (increases Ca absorption and therefore leads to hypercalciuria)
- furosemide (increases Ca excretion by the kidney)
- acetazolamide (alkalinizes the urine)
- uricosuric agents e.g. salycates, probenecid