

# CANADIAN UNDERGRADUATE UROLOGY CURRICULUM



## URINARY CALCULUS DISEASE

# A Message from CanUUC

This educational material is intended to supplement medical student knowledge on urological health and medical practices. We are committed to promoting inclusion across all our materials. We acknowledge that some language used within this content may include terminology from source materials and research studies, which has been maintained to reflect the scientific context in which information was gathered.

Wherever possible, we aim to use language that is respectful of all individuals, recognizing gender diversity, variations in sex characteristics, and the importance of inclusive terminology.

# Objectives

1. List the signs/symptoms and differential diagnoses of an acute stone episode
2. Describe the imaging studies available to diagnose renal or ureteral calculi.
3. List the classes of medications effective for treating the pain of renal colic.
4. Outline the basic treatment options for renal and ureteral calculi
5. Describe the clinical scenarios requiring urgent decompression of a ureteral stone.
6. List the basic principles of stone formation and prevention.

# Urinary Calculus Disease

- A condition where solid masses (kidney stones) form in the urinary tract
- Four main types of stones are: calcium oxalate/calcium phosphate, uric acid, struvite (magnesium ammonium phosphate), and cystine
- Also known as nephrolithiasis, urolithiasis, or renal calculus disease
- Lifetime prevalence is up to 15%<sup>1</sup>
- Recurrence rates are 30–50% within 10 years<sup>2</sup>
- Stones can form at any age, but most commonly affect people aged 30 to 60<sup>3</sup>

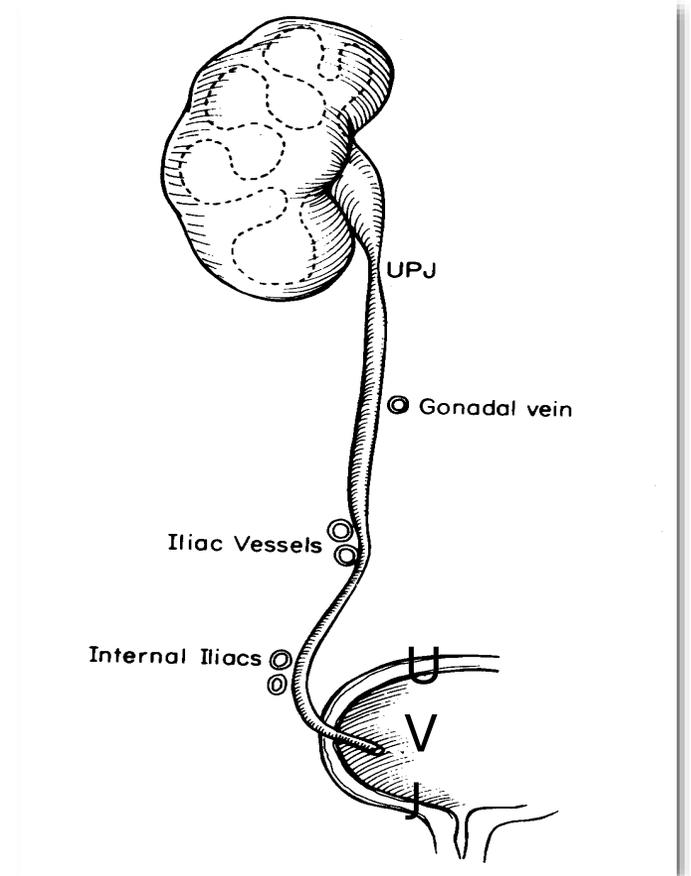
1: Ordon M, Lantz Powers A, Chew BH, Lee JY, Kogon M, Sivalingam S, De S, Bhojani N, Andonian S. Incidence and trends in the treatment of kidney stones in Canada A population-based cohort study. *Can Urol Assoc J*. 2024 Jun;18(6):158-164. doi: 10.5489/cuaj.8596. PMID: 38381927; PMCID: PMC11230698.

2: : Bhojani N, Bjazevic J, Wallace B, et al. UPDATE – Canadian Urological Association guideline: Evaluation and medical management of kidney stones. *Can Urol Assoc J* 2022;16(6):175-88. <http://dx.doi.org/10.5489/cuaj.7872>

3: NHS Inform. (n.d.). *Kidney stones*. Retrieved December 3, 2024, from <https://www.nhsinform.scot/illnesses-and-conditions/kidneys-bladder-and-prostate/kidney-stones/>

# Urinary Calculus Disease: Where do stones get stuck?

1. UPJ: Ureteropelvic Junction where the renal pelvis meets the ureter
2. Pelvic brim: at the level of the common iliac vessels
3. UVJ: Uretero-vesical junction where the ureter meets the bladder



# Physiology of Renal Obstruction

- In cases of acute unilateral obstruction, the affected kidney responds in phases to stone blockage.
- First 2 hours: Increase in renal pelvic pressures and renal blood flow. Due to increased pressure, GFR decreases.
- 6-24 hours: Pressures stay high but renal blood flow goes down.
- After 24 hours: Pressures trend down toward baseline, renal blood flow continues going down. Obstruction, if persistent, eventually leads to renal ischemia.

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# Urinary Calculus Disease: Signs and Symptoms

- Colicky flank pain
  - Rapid onset
  - Unable to achieve comfortable position (writhing)
- Radiates from flank to groin
  - Testis/labia
- Associated nausea/emesis
  - May develop ileus
- Hematuria
  - Gross, microscopic (present in 90%; absence doesn't r/o)
- Irritative LUTS
  - May indicate stone near the UVJ/distal ureter
- BEWARE OF FEVER - **risk of sepsis**

# Urinary Calculus Disease: Differential Diagnosis

- Vascular:
  - AAA
- Bowel:
  - Inflammatory bowel disease, appendicitis, diverticulitis
- Gynecologic:
  - PID, ruptured ovarian cyst, ectopic pregnancy
- Neurologic/Musculoskeletal:
  - Radicular pain, herpes zoster, muscle spasm/strain
- Genito-urinary:
  - Cystitis, pyelonephritis, torsion, UPJ obstruction

# Urinary Calculus Disease: Investigations

AFTER CAREFUL History and Physical Labs:

- Urinalysis (microscopy is gold standard to look for crystals)
- Consider pregnancy test (bHCG)
- CBC & diff (Look for ↑WBC, creatinine (r/o renal failure))

Imaging:

- Initial: to minimize radiation exposure, begin with KUB + ultrasound
- Non-contrast Low-Dose CT abdopelvis (NCCT) is standard for confirming urinary stones
- Intravenous pyelogram (IVP) - more or less historical or in remote settings
- Contrast CT with delayed phase can be used for medication metabolite stones (eg Indinavir HIV medication)

# Urinary Calculus Disease: Urinalysis

- 90% will have at least microhematuria
- May have some pyuria
  - May not indicate UTI
- May have crystals
  - Not specific for stone disease

# Urinary Calculus Disease: Diagnosis - Imaging

- KUB + Ultrasound:
  - Demonstrates stone location & degree of obstruction
  - 80-90% of stones are radio-opaque
  - Phleboliths (calcified pelvic vessels) could be mistaken for ureteral stones
- CT (Non-contrast) LOW-DOSE protocol
  - Reduced-dose NCCT scans have been shown to maintain sensitivities and specificities from 90–97% and can identify alternate diagnoses
  - Quick, most sensitive for renal colic
  - R/o concurrent intra-abdominal pathology

# Diagnosis: KUB

## Advantages:

- 80-90% of stones are radio-opaque
- Minimal radiation

## Disadvantages:

- No detection of concurrent pathology
- Bowel gas
- Easy to miss mid-ureteral stones over the sacrum

# Diagnosis: Non-Contrast “Renal Colic” CT

## Advantages:

- All stone types visible except indinivir
  - » SN - 97%; SP - 96%
- Rapid
- Readily available
- Does not require contrast
- Other pathology identified
- Information about stone and collecting system obtained

# Diagnosis:

## Non-Contrast “Renal Colic” Low-Dose CT Abd/Pelvis

### Disadvantages:

- Increased radiation dose compared with KUB
  - » Should always use Low-Dose protocols especially patients with BMI under 30
- Cost
- No physiologic information such as obstruction
- Should be used judiciously to prevent overreliance on CT

# Diagnosis: Non-contrast CT (NCCT)

## What are you looking for?

- Stone size (height and width)
- Stone density (Stones >500HU are opaque on KUB)
- Location
  - Renal (Pelvis; upper, mid, or lower calyx)
  - Ureteral (UPJ, proximal, mid, distal, or UVJ)
- Presence of hydronephrosis or hydroureter
- Evidence of stranding
- Gas in the collecting system
  - Emphysematous (necrotizing) infection
  - Rare but important finding necessitating urgent broad spectrum antibiotics and drainage with NT

# Diagnosis: Non-contrast CT

## Hydronephrosis

(Note the L renal pelvis is dilated when compared with R renal pelvis)



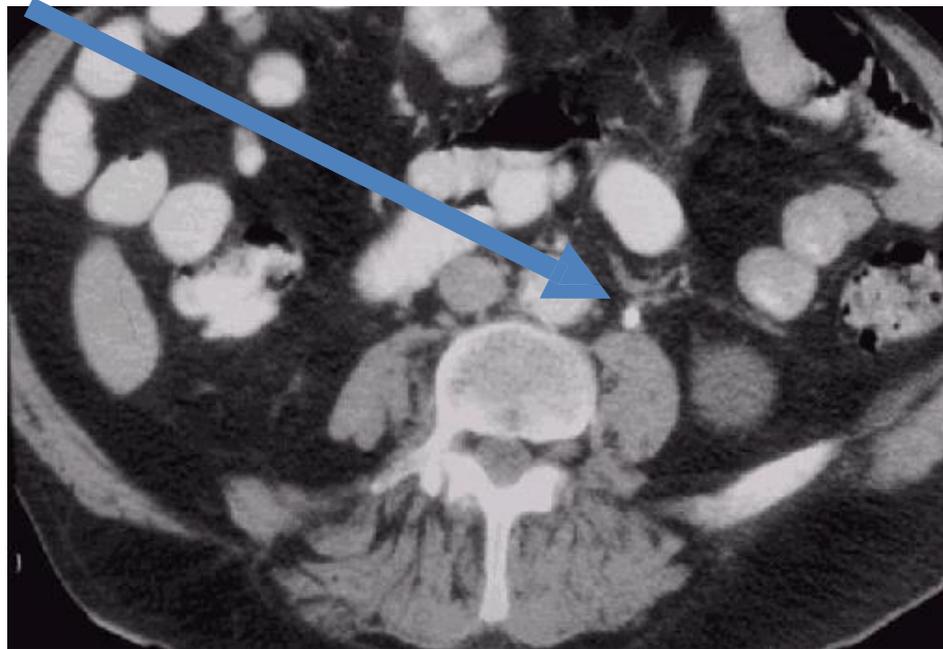
# Non-contrast CT: Ureteral Calculus

Dilated ureter above stone (hydroureter)



# Ureteral Calculus: Non-contrast CT

- Stone visualization & location (i.e. L proximal ureter)
- All stones, except indinavir, are “opaque” on CT
- “Tissue ring” sign



# Calculus Disease: Initial Management of Renal Colic

- Pain control
  - Narcotics
    - Oral/IM/IV
  - NSAIDS (renal function) (Avoid if planning SWL)
    - Oral/rectal/IV
  - Acetaminophen
  - Anti-emetics
- IV hydration (not to force stone passage)
- IF FEVER - CONSULT UROLOGY
  - Discuss antibiotics
- Alpha-blockers as medical expulsive therapy (MET)
  - Tamsulosin (Explain that these are off-label and associated with dizziness and retrograde ejaculation)

# Calculus Disease: Initial Management Based on Size

## **<5mm (renal or ureteral)**

- Discharge home with instructions to drink >2L of water/day
- Tamsulosin for ureteral stones
- 90% will pass spontaneously
- Should follow-up with urology within 1-2 weeks
  - Fear is silent obstruction (painless) with UPJ or proximal ureteral stones leading to irreversible renal loss

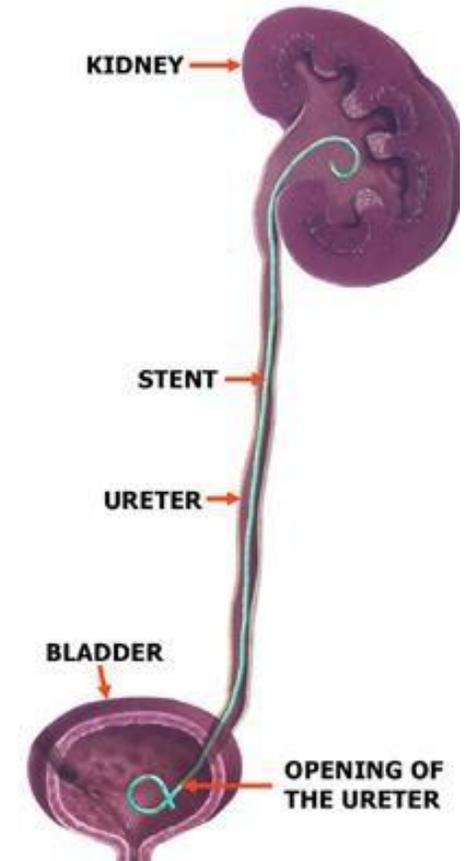
## **>5mm or signs of obstruction**

- Consult urology
- +/- tamsulosin

# Urinary Calculus Disease: CONSULT UROLOGY URGENTLY IF

- Obstructing stone + FEVER/Infection
- Bilateral Ureteral Stones
  - Renal failure
- Solitary Kidney
  - Impending renal failure

These require urgent decompression with ureteral (double J) stents or nephrostomy



# Urinary Calculi: Treatment

1. Extracorporeal shock wave lithotripsy (SWL)
  - Proximal (upper) ureteral stones <1cm or renal stones <2cm
2. Ureteroscopic laser lithotripsy (URS)
  - Mid and distal ureter stones or SWL failures
3. Percutaneous nephrolithotomy (PCNL)
  - Large >2cm renal stones

# Renal Calculi: Clinical Points

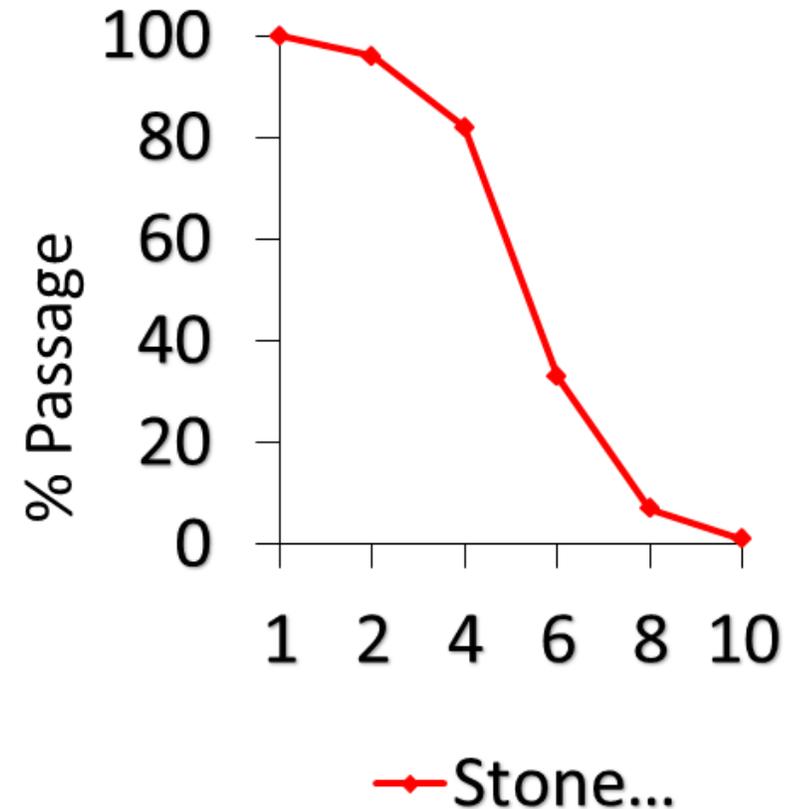
Spontaneous stone passage depends on:

- 1) Location: Proximal vs. distal (distal stones more likely to pass)
- 2) Size: ~90% of stones <5mm will pass
- 3) Time since onset: Most stones pass by ~40 days

# Stone Size: Probability of Stone Passage

Probability of passage:

- <4mm- ~90%
- 4-7mm- ~50%
- >7mm- <10%



# Urinary Calculus Disease Treatment: Extra-corporal Shockwave Lithotripsy (SWL)

- Least invasive
- Conscious sedation
- Fragments stones that the patient then passes
- High patient satisfaction
- May require more time to become stone free
- Renal calculi <2cm or ureteral calculi <1cm



# SWL: Absolute Contraindications

- Pregnancy
- Bleeding Disorder/anticoagulation  
(NSAIDS pre-op)
- Febrile UTI
- Obstruction Distal to the stone being treated

# SWL: Relative Contraindications

- Radiolucent stones due to difficulty in localizing. To localize these stones:
  - Could use ultrasound
  - Could use retrograde pyelography or IVP
- Pacemaker (Need to use gated shockwaves; Pacemakers in the path of shockwaves could be damaged)
- Calcified renal artery/AAA
- Severe orthopedic deformities

# Post SWL follow-up:

- Tamsulosin improves stone-free rates
- KUB in 2-4 weeks post-treatment
- May continue to pass fragments for several weeks
- Ultrasound to rule out silent obstruction

# SWL success depends on:

- Stone Size (Better if <1 cm)
- Stone Location (Better if renal pelvic or upper ureter)
- Stone Density/ Composition (Better if HU<1000)
  - Hounsfield unit density on NCCT
- Patient Habitus (Better if skin-to-stone distance <10cm)
- Worse if associated renal anomalies:
  - UPJ Obstruction
  - Horseshoe kidney

# Complications of SWL

- Hematuria
- Ureteral obstruction - 5-30%
  - Depends on size of initial stone
  - “steinstrasse” (stone fragments obstructing ureter)
  - Intervention as per other ureteral stones
- Sepsis - 1%
- Perinephric Hematoma - <1%
- Hypertension/DM- no convincing evidence that SWL leads to long term HTN or DM

# When do we not use SWL?

- Stone Burden
  - >2cm in largest diameter or multiple stones
- Stone composition
  - Particularly cystine or brushite stones
  - Hounsfield units >1000
- Patient needs to be stone-free for occupation
  - Pilots, firefighters
- Patient habitus (skin-to-stone distance >10cm)
- Failed SWL
  - 2nd treatment reasonable
  - Diminishing returns of 3 or more treatments

# Ureteroscopy for Ureteral Stones

## Advantages:

- Near 100% stone free rate
- Low retreatment rates
- Treatment available in most centres
  - SWL tends to be in regional centres only

## Disadvantages:

- Anesthesia is usually required
- Ureteral stent (DJ) may be left
  - Stent symptoms are bothersome to patients
- Lower patient satisfaction

**Typically for ureteral calculi and SWL failures**



# Ureteroscope Equipment:

Scopes are either:

- Semi-rigid
- Flexible

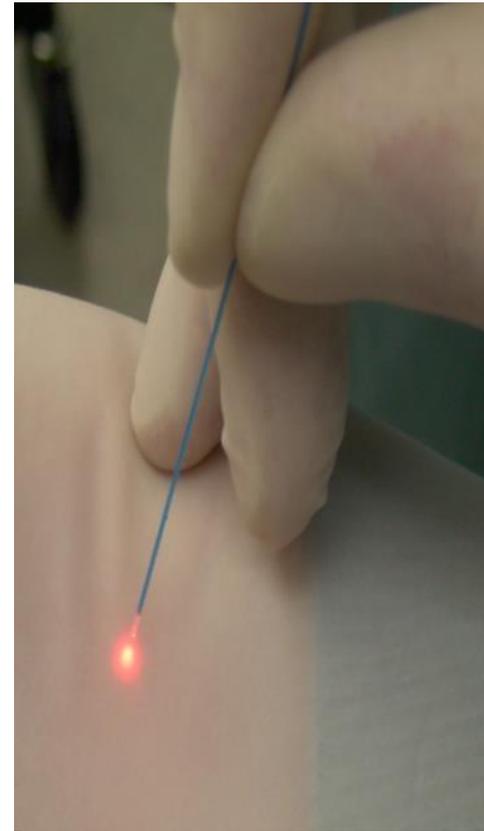
Stone Fragmentation:

- Holmium: YAG or thulium laser

Stone Retrieval:

- Baskets
- Graspers
- Flexible and navigable suction ureteral access sheaths

\*One of the best innovations in urology over the last 2 decades\*



# Urinary Calculus Disease: Percutaneous Nephrolithotripsy

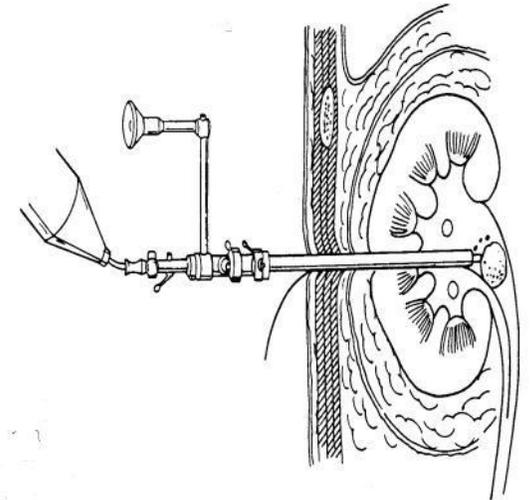
Typically for large (>2cm) renal calculi

## Advantages:

- Ability to remove large or multiple stone burden with high success rate (>95%)

## Disadvantages:

- General anesthesia
- More invasive than URS
- Risk of bleeding <5% require transfusion
- Injury to surrounding organs
- Risk of hydropneumothorax



# Percutaneous Nephrolithotripsy: Complications

- Sepsis or Systemic Inflammatory Response Syndrome (SIRS)
- Bleeding requiring transfusion or selective angioembolization
- Perforation of the renal pelvis
- Stricture
  - UPJ or infundibulum
- Residual stone fragments
- Hemothorax/pleural effusion (<10%)
- Adjacent organ injury (colon perforation)

# Stone Prevention

# Stone Prevention: Basic Work-Up for ALL PATIENTS

- Urinalysis and culture:
  - Urea splitting organisms (Proteus, Pseudomonas, Klebsiella, mycoplasma, Serratia, Staph Aureus)
  - Acidic urine - uric acid or cystine stones
  - Alkaline urine – calcium phosphate stone or struvite stones
- Serum electrolytes (Na, K, Cl, HCO<sub>3</sub>), urea, creatinine, uric acid and calcium
- If elevated or normal high serum calcium then obtain PTH to rule out Primary Hyperparathyroidism
- Send stone for analysis

# Stone Prevention: Detailed Metabolic Work-Up Indications

- Children (<18 years of age)
- Bilateral, recurrent or multiple stones
- Non-calcium stones (e.g., uric acid, cystine)
- Pure calcium phosphate stones
- Complications from stones (AKI, sepsis, or admission)
- Any stone requiring percutaneous nephrolithotomy
- Solitary kidneys (anatomical or functional)
- Patients with renal insufficiency
- Systemic disease (gout, osteoporosis, bowel disorders, hyperparathyroidism, renal tubular acidosis, etc.)
- High-risk occupations where stone events could impair public safety (e.g. pilots, military, police)
- Interested first time stone formers

# Stone Prevention: Detailed Metabolic Work-Up

In addition to the Basic metabolic work- up, it includes:

- Two 24-hour urine collections:
- Volume, creatinine, calcium, sodium, potassium, oxalate, citrate, uric acid, magnesium +/-cystine if the stone analysis is cystine

# Stone Prevention: General Advice

Increase Hydration to 2-3L per day to achieve daily urine output of 2.5L Diet:

- Maintain normal calcium intake (1000-1200mg with meals)
  - Used to advice low calcium diets – Proven to be false
- Minimize foods high in oxalate (Spinach, peanut, rhubarb)
- Minimize salt (<2300mg/d) and animal protein
- Increase fiber, vegetables and citrus-rich fruits

Consider urinary alkalinization:

- Mainly for uric acid and cystine stones
- Potassium citrate - preferred
- Sodium citrate or bicarbonate - alternative

# Stone Prevention: Calcium Stones (80%)

- Most stones are calcium oxalate
- Some are calcium phosphate or mixed
- Etiology
  - Hypercalciuria
    - Increased intestinal absorption
    - Bone resorption ( $\uparrow$ PTH)
    - Renal leak
  - 25% also have hyperuricosuria
  - Hyperoxaluria
    - Usually increased intestinal absorption – small bowel resection/IBD
    - Ingestion of oxalate-rich foods
  - Hypocitraturia

# Stone Prevention: Prevention of Calcium Stones

- Hydration - 2-3L of urine per day
- Normal dietary calcium intake (1000-1200mg/d)
- Dietary limitations:
  - Salt - potentiates hypercalciuria
  - Oxalates – Tea/chocolate/Spinach/Rhubarb
  - Animal protein
- Consider Thiazide for hypercalciuria
- Consider potassium citrate for hypocitraturia

# Stone Prevention: Struvite Stones (5-10%)

- Triple phosphate
  - Calcium Magnesium, ammonium phosphate
- Alkaline urine pH due to urea splitting organisms
  - Proteus, Pseudomonas, Klebsiella, Mycoplasma, Serratia, Staph Aureus
  - NOT E COLI
- Must clear all stone material and infection
  - SWL often not useful
- May form staghorn stones quickly

# Stone Prevention: Uric Acid Stones (10%)

- Radiolucent - not visible on KUB
- Occur in patients with low urine volume and acidic urine (pH<6.0)
  - Purine-rich diets
  - High cell turnover - cancer treatment
- Prevention:
  - Hydration
  - Decrease protein intake
  - Alkalinize urine
    - Potassium citrate or sodium bicarbonate

# Stone Prevention: Cystine Stones

- Usually first detected in children
  - Often positive family history
- Defect in absorption of dibasic amino acids
  - COLA (cystine, ornithine, lysine, arginine)
  - Only cystine is insoluble
- Rapid formation of staghorn stones
- Must remove all stone material aggressively
  - SWL has limited application
- Prevention:
  - Hydration (Need to produce >3L of urine per day)
  - Low salt and animal protein
  - Alkalinize urine (cystine is soluble in alkaline urine)
  - Penicillamine, thiola (disulfide bond binders)

# Take Home Points: Urinary Calculi

- KUB + ultrasound is a useful first investigation
- Low-Dose non-contrast CT is the most sensitive test
- Fever with an obstructing ureteral stone requires emergent intervention (decompression – stent/nephrostomy)
- Obstructing stones in a solitary kidney require emergent attention