# Kidney Stone Management

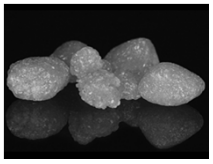
**Bodo E. Knudsen, MD, FRCSC**
**Director, OSU Comprehensive Kidney Stone Program**
**Associate Professor, Henry A. Wise II Endowed Chair**
**Vice Chair, Department of Urology**
**The Ohio State University Wexner Medical Center**

# Disclosures

- **Consultant – Boston Scientific**
- **Consultant - ThermDX**
- **Course Instructor – Coloplast**

# Introduction

- **Prevalence and Cost**
- **Overview of diagnostic imaging**
- **Surgical options**



# Prevalence

- **Prevalence in the U.S. – 8.8%**
  - **Male – 10.6%**
  - **Female – 7.1%**
  - **Obese – 11.2%**
  - **Normal wt – 6.1%**
- **Both obesity and diabetes strongly associated with stone disease**
- **Marked increase from 1 in 20 in 1994**

**Scales et al, Eur Urol, Jul, 2012**

*1 out of every 11 American will experience a kidney stone during their lifetime*

# Costs

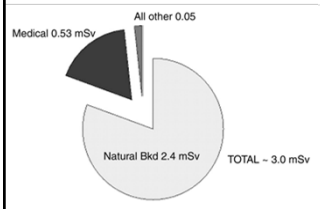
- In 2000:
  - Evaluation/treatment of stones > $2.07 billion in the U.S.
  - Inpatient stays - 177,496 adults with stones as primary diagnosis
  - Outpatient – ≈ 2,700,000 visits for "urolithiasis"

Source: NIDDK: National Kidney and Urologic Diseases Information Clearinghouse

# Imaging in Stone Disease

# Increase in Radiation Exposure

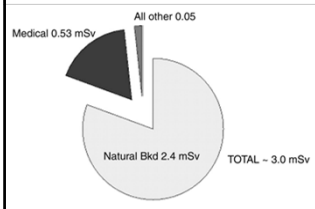
1980



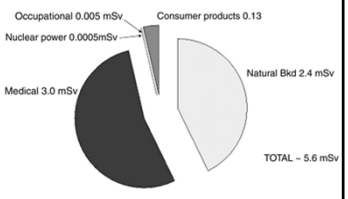

Figures 1a, 1b
Mettler F A, Bhargavan M, Faulkner K, et al. Radiologic and nuclear medicine studies in the United States and worldwide: Frequency, radiation dose, and comparison with other radiation sources—1950-2007. *Radiology* 2009;253:520-531.

# Increase in Radiation Exposure

1980

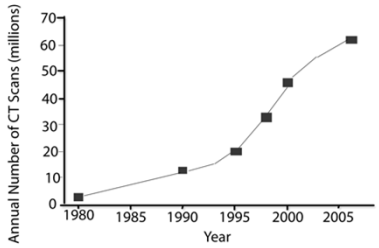



2006




Figures 1a, 1b
Mettler F A, Bhargavan M, Faulkner K, et al. Radiologic and nuclear medicine studies in the United States and worldwide: Frequency, radiation dose, and comparison with other radiation sources—1950-2007. *Radiology* 2009;253:520-531.

## Increase in CT Imaging




N Engl J Med 2007; 357:2277-2284

## ALARA

- ALARA is an acronym for As Low As Reasonably Achievable. This is a radiation safety principle for minimizing radiation doses and releases of radioactive materials by employing all reasonable methods. ALARA is not only a sound safety principle, but is a regulatory requirement for all radiation safety programs.

Radiation Safety and ALARA
https://www.ncsu.edu/ehs/radiation/forms/alara.pdf

## Pre-operative Imaging: Plain Abdominal Radiograph (KUB)

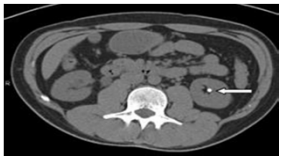
- KUB
  - Sensitivity - 58 – 62%
  - Specificity - 67 – 69%
  - Calcium containing stones most easily visualized, especially dense CaOx monohydrate and CaP brushite
  - Pure uric acid – radiolucent
  - Inexpensive

## Pre-operative Imaging: Renal Ultrasound

- Renal ultrasound
- Sensitivity ≈ 60%
- Sensitivity and specificity are operator and patient body habitus dependent
- Large stones in the kidney and hydronephrosis readily appreciated
- Small stones, ureteral stones, and multiple stones may be difficult to assess
- Most often used during follow up and pregnancy

## Pre-operative Imaging: Non-contrast Enhanced Helical CT (NCCT)

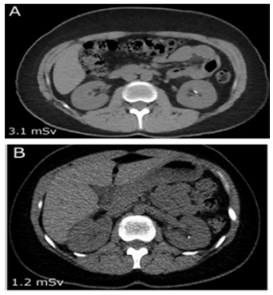
- NCCT
  - Sensitivity approaching 100%
  - Specificity ≈ 97%
  - Readily available at most centers including ER's
  - May identify other intra-abdominal pathology
  - Can assess presence but not *degree* of obstruction



Yilmaz, Eur Rad, 1998; Boulay, AJR, 1999; Chen, J Emerg Med, 1999; Pearle, J Urol, 1999; Pfister, Eur Rad, 2003

## Pre-operative Imaging: Low Dose CT (LDCT)

- Ability to significantly decrease radiation exposure
  - 10 mSv reduced to < 3 mSv
- Some limitations with small (< 2 mm) stones and stones in the mid to distal ureter
- Dose reduction less in obese patients (BMI > 30)
- Secondary signs of obstruction, such as perinephric stranding may be more difficult to visualize




Zilberman, J Urol, 2011; Uppot, Rad Rnds, 2011

## Surgical Management of Stones

- AUA in 2016 updated their guidelines for the surgical management of stones.
- Primary options remain watchful waiting, shockwave lithotripsy (ESWL), ureteroscopy and laser lithotripsy, and percutaneous nephrolithotomy (PCNL)
- Minimal role for open stone surgery in 2016

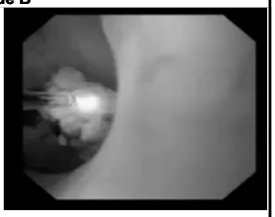
## AUA Surgical Stone Guidelines

- Factors considered:
  - Size of stone
  - Location of stone
  - Symptomatic?
  - Hx of infection

## Symptomatic Patient with Total Non-Lower Pole Stone Burden < 20 mm: SWL vs URS

**Strong Recommendation**
**Evidence Level Grade B**

- Stone-free rates acceptable via SWL and URS
  - Less morbidity than PCNL
- URS associated with lower risk of repeat procedure → stone-free quicker than SWL
- SWL advantage: non-invasive, pt preference, lack of stent
- Requires shared decision-making process

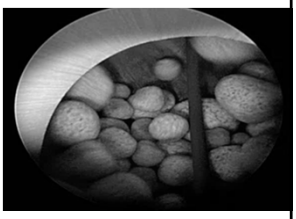


SWL = Shock Wave Lithotripsy URS = UReteroScopy
PCNL = PerCutaneous NephroLithotomy

## Symptomatic Patient with Total Non-Lower Pole Stone Burden > 20 mm: PCNL

**Strong Recommendation**
**Evidence Level Grade C**

- PCNL has higher stone free rate than SWL or URS
  - Less invasive than open or laparoscopic/robotic surgery
  - Less affected by stone location, composition or density
- Increased invasiveness and risk of complications



SWL = Shock Wave Lithotripsy URS = UReteroScopy
PCNL = PerCutaneous NephroLithotomy

## SWL should not be offered as first-line therapy for total renal stone burden > 20 mm

**Moderate recommendation**
**Evidence Level Grade C**

- Significantly reduced stone free rates
- Increased need for multiple treatments vs PCNL
- Risk of steinstrasse/ureteral obstruction increases
  - > 2 cm stone → 24.3%
  - 1-2 cm stone → 15.9%
  - < 1cm stone → 4.5%


Soyupek et al. Urol Int 2005
Madbouly et al. J Urol 2002
Al-Awadi et al. BJU Int 1999

## Staghorn stones

**Clinical Principle**

- Should be removed if attendant co-morbidities do not preclude treatment
  - Risk for deterioration of renal function
  - Loss of kidney
  - ESRD
  - Infectious complications
  - Mortality
- Older series more infection stones
- Newer series more metabolic stones

## Symptomatic ≤ 10 mm Lower Pole Renal Stones

**Strong Recommendation**
**Evidence Level Grade B**

- First-line therapy:
  - SWL
  - URS
- Multi-center, prospective RCT
  - No statistically significant difference in stone free rates
  - Intraop complications slightly higher with URS
  - Pt derived QOL measures better with SWL

Pearle et al. J Urol 2005

## Symptomatic ≤ 10 mm Lower Pole Renal Stones

**Strong Recommendation**
**Evidence Level Grade B**

- CT imaging parameters to aid in pt selection
  - Skin-to-stone distance
    - > 9-10 cm → URS
    - < 9-10 cm → SWL
  - Stone attenuation
    - > 900-1000 HU → URS
    - < 900-1000 HU → SWL


## > 10 mm Lower Pole Renal Stones

**Strong Recommendation**
**Evidence Level Grade B**

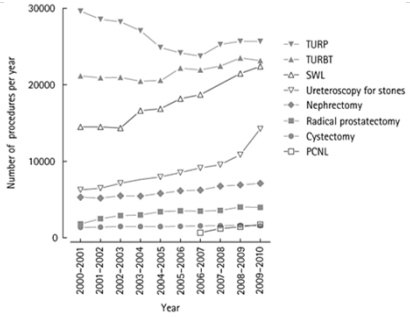
- First-line therapy:
  - URS or PCNL
  - Both have better stone free rate than SWL
  - Moderate associated increase in risk with PCNL
- Should not offer SWL as first-line therapy
- URS and SWL
  - Higher re-treatment rates
  - SFR significantly lower
  - Higher likelihood of clinical recurrence due to retained fragments

## Asymptomatic Non-obstructing Caliceal Stones

**Conditional Recommendation**
**Evidence Level Grade C**

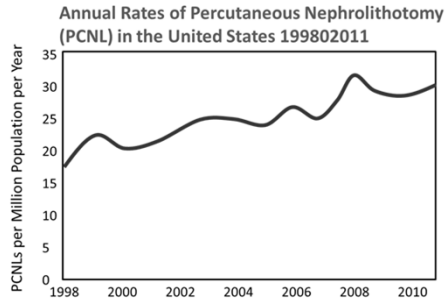
- Clinicians may offer active surveillance
- Counsel pts
  - Risk of stone growth
  - Passage
  - Pain
- Serial imaging
- Dietary modifications
- Medical therapy

## Increase in URS Procedures




Turney, B. W., Reynard, J. M., Noble, J. G. and Keoghane, S. R. (2012), Trends in urological stone disease. BJU International, 109: 1082–1087. doi:10.1111/j.1464-410X.2011.10495.x

## Increase in PCNL Procedures




Stern, Urol, 2016 - http://dx.doi.org/10.1016/j.urology.2015.12.080

# Conclusions

- Common condition with 1:11 American's experiencing stone in their lifetime
- Imaging highly sensitive with focus now on reducing radiation exposure
- ESWL, URS with laser lithotripsy, and PCNL remain cornerstones of surgical therapy

# Kidney Stones:
## Medical Management and Prevention

**Ganesh Shidham, MD**
**Associate Professor**
**Division of Nephrology**
**The Ohio State University Wexner Medical Center**

# Outline

- **Types of Kidney stones**
- **Evaluation**
- **Identify Risk factors for kidney stone**
- **Medical management**
  - **Treatment of risk factors**

# Types of Stones

| Type | Frequency % | Characteristics |
|---|---|---|
| **Calcium Stones** | **70-88** | **M>F, radiodense** |
| **Oxalate** | **36-70** | **in acidic pH** |
| **Phosphate** | **6-20** | |
| **Mixed** | **11-31** | **in alkaline pH** |

# Types of Stones

| Type | Frequency % | Characteristics |
|---|---|---|
| Non-Calcium Stones 22-30% | | |
| $MgNH_4PO_4$ (Struvite) Triple phosphate | 6-20 | F>M, radiodense, staghorn, alkaline pH >8, infection with urea splitters (proteus) |
| Uric Acid | 6-17 | M>F, radiolucent, acidic pH |
| Cystine | 0.5-3 | F>M in homozygotes, radiodense, acidic pH |
| Rare stones | Rare | Xanthine, triamterene, indinavir, ephedrine |

# Who To Investigate?

*Active stone disease* and *recurrent* stone formers : need full work up

- Metabolic abnormalities in 96% (Levy et al)

*First time* stone former:

- Large stone, Needing urologic procedure, Needing hospital stay, complicated by sepsis : should get complete evaluation
- Small stone passed spontaneously: Limited w/u is sufficient with increase in fluid intake.

## Evaluation
### Clinical

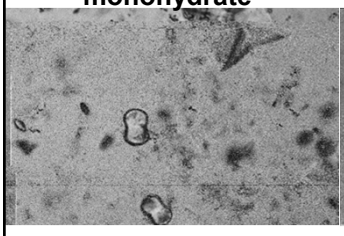
Detailed evaluation is best postponed until free of symptoms and eating normally.

- Dietary history: fluid, protein, oxalate, Na, Calcium
- Medications
- Family history (significant risk for recurrence)
- Medical illnesses: Recurrent UTI, IBD, gout, neoplasm, HPTH, hyperthyroidism, RTA
- Previous stones and interventions
- Is the disease active?

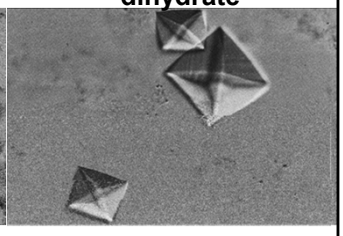
## Evaluation
### Lab Studies

- Stone analysis
- Blood profile
- Urine metabolic evaluation
- Urine Microscopy - crystals
- Imaging: (for baseline stone burden)
    - CT scan with stone protocol
    - US kidney
    - KUB

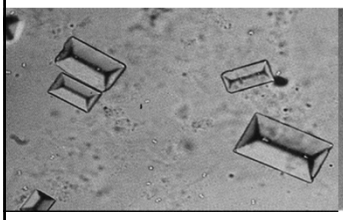
**Cal Ox monohydrate**



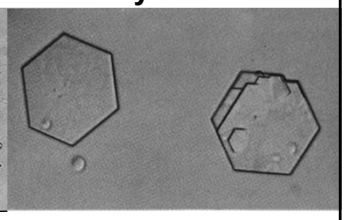
**Cal Ox dihydrate**



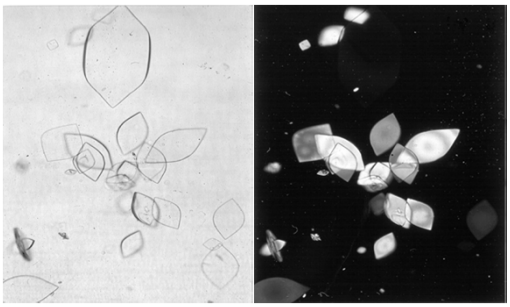
**Struvite**



**Cystine**



# Uric Acid



# Evaluation

## 24-Hour Urine Testing

- Volume
- pH
- Calcium
- Oxalate
- Uric Acid
- Citrate
- Sodium
- Potassium
- Creatinine
- Urea
- Phosphorus
- SS CaOx
- SS CaP
- SS Uric acid

**Summary Stone Risk Factors**

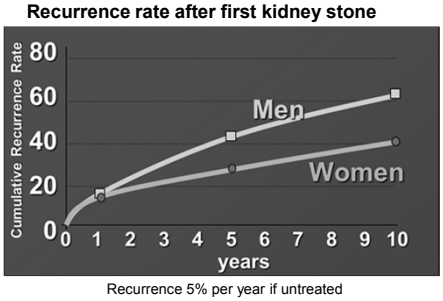
SAMPLE ID: S809652 PATIENT COLLECTION DATE: 03/02/2011

| ANALYTE | ← DECREASED RISK | INCREASING RISK FOR STONE FORMATION → |
|---|---|---|
| Urine Volume (liters/day) | ● 2.25 | |
| SS CaOx | ● 3.16 | |
| Urine Calcium (mg/day) | ● 183 | |
| Urine Oxalate (mg/day) | ● 23 | |
| Urine Citrate (mg/day) | | 214 ● |
| SS CaP | ● 0.17 | |
| 24 Hour Urine pH | | ● 5.448 |
| SS Uric Acid | ● 1.10 | |
| Urine Uric Acid (g/day) | ● 0.504 | |

**Report from Litholink Laboratory**

# Recurrence of Stones

**Recurrence rate after first kidney stone**

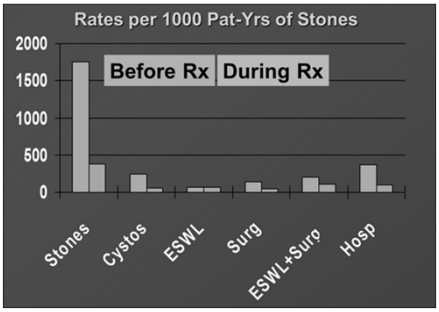



Recurrence 5% per year if untreated

Uribarri, et al, Ann Intern Med 1989; 111;1006

# *Medical Management*

## Before and During Medical Treatment




Data from Parks & Coe, 1996. University of Chicago

## Risk Factors for Calcium stones

1.Hypercalcuria (40-75%)
- A. With hypercalcemia
  - Hyperparathyroidism
  - Granulomatous diseases
  - Hyperthyroidism
  - Malignancies, Immobilization
- B. Without Hypercalcemia
  - Type 1 RTA
  - High protein intake, High salt intake
  - **Idiopathic Hypercalciuria** (most common)

## Risk Factors for Calcium stones

2. Hyperuricosuria (30-50%)
   - Purine rich diet, gout, alcohol,
   - Metabolic syndrome, Inborn errors
3. Hypocitraturia (10-50%)
   - Type 1 RTA
   - Diarrheal diseases
   - High dietary animal proteins

## Risk Factors for Calcium stones

4. Hyperoxaluria (<5%)
   - Primary hyperoxaluria
   - Enteric hyperoxaluria (malabsorption)
   - Post Bariatric surgery
   - Oxalate rich foods, Ascorbic acid
5. Anatomic risk factors:
   - Medullary Sponge kidney
   - Horseshoe Kidney
   - Polycystic Kidney disease

## Risk Factors for Calcium Stone

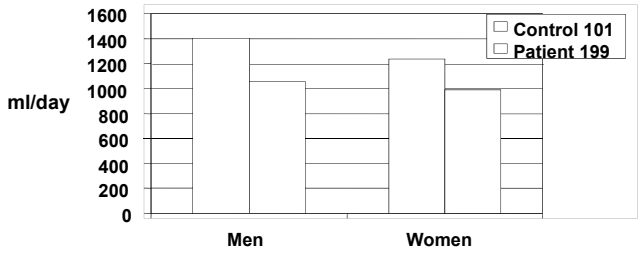
1. Low Urine Volume
2. Hypercalcuria
3. Hyperoxaluria
4. Hypocitraturia
5. High Na intake
6. High protein intake
7. Hyperuricosuria

*Treatment of Risk Factors*

## Low Urine Volume

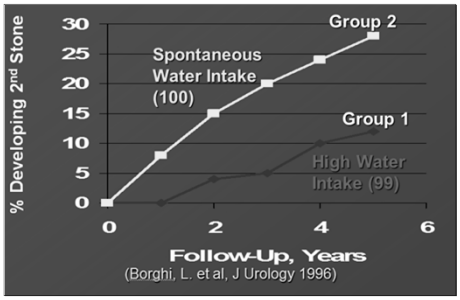
| | |
|---|---|
| **Definition** | **Urine output < 1 L/day** |
| **Treatment** | **- Increase water intake.<br>- Avoid sugar, salt, or Phosphoric acid containing carbonated beverage** |
| **Goal** | **Urine volume >2 L /day** |

## Urine Volumes in Kidney Stone Patients




(Borghi, L. et al, J Urology 1996)

## Effect of Increased Water on Stone Recurrence




## Case 1

56 y man with CaOx stones. Passed multiple stones since 2005. ESWL in 2005 for right sided stone, ESWL 2009 for left sided stone.

| Serum | Na | K | Cl | CO2 | Creat | Ca | Mg | P |
|---|---|---|---|---|---|---|---|---|
| 2/2/09 | 139 | 4.3 | 105 | 26 | 0.9 | 11.8 | 2.1 | 1.9 |

| Urine | Vol24 | Ca24 | Ox24 | Cit24 | UpH | Cr24 | Na24 | UA24 | CaOxSS |
|---|---|---|---|---|---|---|---|---|---|
| 2/2/09 | 1.81 | 402 | 37 | 712 | 6.3 | 1700 | 134 | 0.64 | 8.2 |
| Normal | 2.00 | <250 | 20-40 | >450 | 5.8-6.2 | | 50-150 | <0.80 | 4-6 |

Next appropriate test?
What therapy is appropriate?

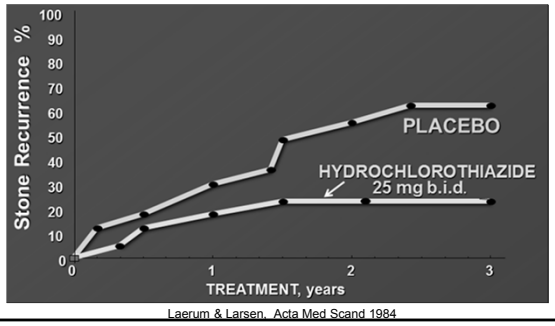
## *Treatment of Risk Factors* Hypercalciuria

**Definition** — **Urine Ca > 4 mg/kg/day**

**Treatment**
1. **Urine output >2 L/day**
2. **↓ dietary protein & NaCl**
3. **HCTZ 25 mg PO BID (↓Urine Ca by 40-60%)**
4. **Maintain normal Ca diet**
5. **Avoid Calcium supplements**

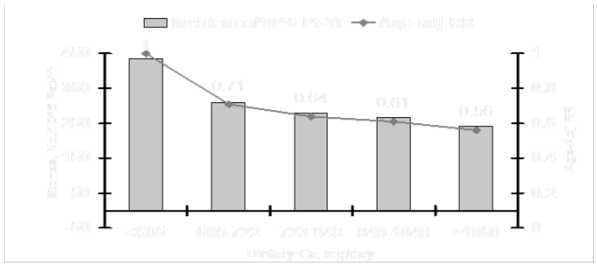
**Goal** — **Urine Ca < 4 mg/kg/day**

## Hypercalciuria: Thiazides & Stone Recurrence



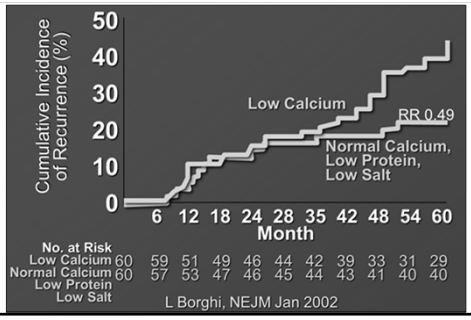

Laerum & Larsen, Acta Med Scand 1984

## **Myth:** *High Calcium Intake Leads to Kidney Stones*



Curhan, NEJM 1993

## Hypercalciuria: Recurrent Stones According to Diet




## *Treatment of Risk Factors* Hyperoxaluria

| | |
|---|---|
| **Definition** | **Urine oxalate >45 mg/day** |
| **Treatment** | **1. Urine Output >2 L**<br>**2. Diet low in oxalate, ascorbic acid**<br>**3. Calcium supplements** |
| **Goal** | **Urine Oxalate < 45 mg/day** |

## Case 2

21 yrs old man with H/O kidney stones.
He has CT scan showing bilateral stones and areas of Nephrocalcinosis.

| Serum | Na | K | Cl | CO2 | Creat | Ca | Mg | UA |
|---|---|---|---|---|---|---|---|---|
| 10/6/02 | 131 | 4.4 | 106 | 15 | 1.4 | 9.9 | 2.2 | 7.2 |

| Urine | Vol 24 | Ca24 | Ox24 | Cit24 | UpH | Na24 | Cr24 | UA24 | UASS |
|---|---|---|---|---|---|---|---|---|---|
| 12/02 | 1.2 | 177 | 31 | 72 | 6.8 | 106 | 1632 | 0.599 | 0.8 |
| 12/04 | 1.02 | 144 | 30 | 82 | 6.5 | 117 | 1566 | 0.654 | 1.0 |
| Normal | 2.00 | <250 | 20-40 | >450 | 5.8-6.2 | 50-150 | varies | <.800 | 0-1 |

Where is the problem?
What is the treatment?

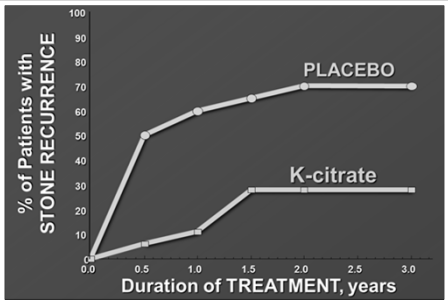
## *Treatment of Risk Factors*
## Hypocitraturia

**Definition** Urine citrate <350 mg/day

**Treatment**
1. Urine output > 2 L/day
2. K Citrate 20 mEq TID
3. Normal protein diet
4. Sod Bicarbonate

**Goal** Urine citrate >350 mg/day
Normal plasma Bicarb

## Effect of K-Citrate on Stone Recurrence




Barcelo P, J Urolo 1993

## *Treatment of Risk Factors*
## High Na+ Intake

**Definition:** Urine Na >100 mmol/day

**Effect:** -Urinary Ca

**Treatment:** Low salt diet
(<100 mmol sodium/day)
(<2 gm sodium/day)

**Goal:** Urine Na < 100 mmol/day

## Case 3 /////// add

34 yo body builder male with H/O renal colic. Passed two stones in 1998. Had 4 episodes of kidney stones since then.

| Serum | Na | K | Cl | CO2 | Creat | Ca | Mg | UA |
|---|---|---|---|---|---|---|---|---|
| 10/6/01 | 141 | 4.4 | 106 | 28 | 0.9 | 9.9 | 2.2 | 7.2 |

| Urine | Vol24 | Ca24 | UUN | Cit24 | UPO4 | Cr24 | Na24 | UA24 | UASS |
|---|---|---|---|---|---|---|---|---|---|
| 10/01 | 1.1 | 319 | 24 | 323 | | 2401 | 253 | 1.50 | 3.4 |
| 7//01 | 1.0 | 298 | 26 | 212 | | 2427 | 242 | 1.44 | 3.9 |
| Normal | 2.0 | <250 | | >450 | | | 50-150 | <0.80 | 0-1 |

## *Treatment of Risk Factors*
## High Protein Intake

**Definition** Dietary Protein > 1gm/kg

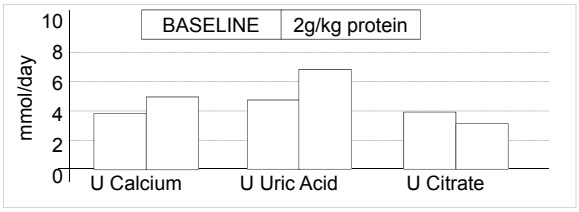
**Effect** Increases Urine Ca, Uric acid and decreases Citrate

**Treatment** Decrease intake of animal protein

**Goal** Protein intake ~ 1g/kg

Estimated dietary protein
= 6.25(24 hr urine urea nitrogen in gm + 0.03/kg body weight)

## Protein Load Increases Urine Stone Forming Tendency




J Cli Endocrinol Metab 1990;71:861

## *Treatment of Risk Factors*
## Hyperuricosuria

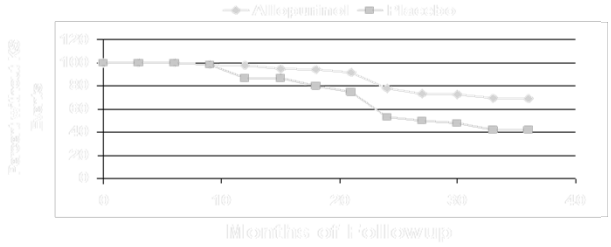
**Definition** Urine uric acid >750 - 800 mg/day

**Effect** Nucleation of CaOx on uric acid

**Treatment**
1. ↓ dietary purines
2. Alkaline urine pH ~ 6.5
   (Solubility of uric acid-
   Acidic urine - 100 mg/L
   At pH 7 – 1600 mg/L)
3. K Citrate
4. Allopurinol

**Goal** Urine uric acid < 750-800 mg/day

## Allopurinol in Hyperuricosuric Ca Stone Formers



Ettinger et al, 1988

# Non Calcium stones

- **Uric acid stones**
- **Struvite/Infection stones**
- **Cystine stones**

## Take Home Messages

*Hard Facts About True Grit*

- Nephrolithiasis is Common disease causing fair amount of morbidity & large economic burden
- Systemic disease associated with HTN, Obesity, DM, CAD, Metabolic syndrome and bone disease
- Identifying risk factors is important
- Simple treatments –like dietary & fluid modification can slow or prevent future stone development
- Increasing fluid intake to make > 2 Lts of urine per day is first line of treatment for stone preventions