Kidney Stone Management

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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


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

Medical 0.53 mSv
All other 0.05
Natural Bkd 2.4 mSv
TOTAL ~ 3.0 mSv

1980

Medical 0.53 mSv
All other 0.05
Natural Bkd 2.4 mSv
TOTAL ~ 3.0 mSv

2006

Occupational 0.005 mSv
Nuclear power 0.0005mSv
Medical 3.0 mSv
Consumer products 0.13
Natural Bkd 2.4 mSv
TOTAL ~ 5.6 mSv

Figures 1a, 1b
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)

<table>
<thead>
<tr>
<th>KUB</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity - 58 – 62%</td>
<td></td>
</tr>
<tr>
<td>Specificity - 67 – 69%</td>
<td></td>
</tr>
<tr>
<td>Calcium containing stones most easily visualized, especially dense CaOx monohydrate and CaP brushite</td>
<td></td>
</tr>
<tr>
<td>Pure uric acid – radiolucent</td>
<td></td>
</tr>
<tr>
<td>Inexpensive</td>
<td></td>
</tr>
</tbody>
</table>

## Pre-operative Imaging: Renal Ultrasound

<table>
<thead>
<tr>
<th>Renal ultrasound</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity ≈ 60%</td>
<td></td>
</tr>
<tr>
<td>Sensitivity and specificity are operator and patient body habitus dependent</td>
<td></td>
</tr>
<tr>
<td>Large stones in the kidney and hydronephrosis readily appreciated</td>
<td></td>
</tr>
<tr>
<td>Small stones, ureteral stones, and multiple stones may be difficult to assess</td>
<td></td>
</tr>
<tr>
<td>Most often used during follow up and pregnancy</td>
<td></td>
</tr>
</tbody>
</table>
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


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

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 $\rightarrow$ 24.3%
  - 1-2 cm stone $\rightarrow$ 15.9%
  - < 1 cm stone $\rightarrow$ 4.5%

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

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**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

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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


Increase in PCNL Procedures

Annual Rates of Percutaneous Nephrolithotomy (PCNL) in the United States 1998-2011

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency %</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Stones</td>
<td>70-88</td>
<td>M&gt;F, radiodense</td>
</tr>
<tr>
<td>Oxalate Phosphate</td>
<td>36-70</td>
<td>in acidic pH</td>
</tr>
<tr>
<td>Mixed</td>
<td>6-20</td>
<td>in alkaline pH</td>
</tr>
<tr>
<td></td>
<td>11-31</td>
<td></td>
</tr>
</tbody>
</table>
### Types of Stones

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency %</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-Calcium Stones 22-30%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MgNH₄PO₄ (Struvite)</td>
<td>6-20</td>
<td>F&gt;M, radiodense, staghorn, alkaline pH &gt;8, infection with urea splitters (proteus)</td>
</tr>
<tr>
<td>Triple phosphate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uric Acid</td>
<td>6-17</td>
<td>M&gt;F, radiolucent, acidic pH</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.5-3</td>
<td>F&gt;M in homozygotes, radiodense, acidic pH</td>
</tr>
<tr>
<td>Rare stones</td>
<td>Rare</td>
<td>Xanthine, triamterene, indinavir, ephedrine</td>
</tr>
</tbody>
</table>

### 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
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
Recurrence of Stones

Recurrence rate after first kidney stone

Recurrence 5% per year if untreated

Medical Management

Before and During Medical Treatment

Rates per 1000 Pat-Yrs of Stones

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)

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

<table>
<thead>
<tr>
<th>Definition</th>
<th>Urine output &lt; 1 L/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>- Increase water intake.</td>
</tr>
<tr>
<td></td>
<td>- Avoid sugar, salt, or</td>
</tr>
<tr>
<td></td>
<td>Phosphoric acid</td>
</tr>
<tr>
<td></td>
<td>containing carbonated</td>
</tr>
<tr>
<td></td>
<td>beverage</td>
</tr>
<tr>
<td>Goal</td>
<td>Urine volume &gt;2 L/day</td>
</tr>
</tbody>
</table>

Urine Volumes in Kidney Stone Patients

(Borghi, L. et al, J Urology 1996)
Effect of Increased Water on Stone Recurrence

![Graph showing the effect of increased water intake on the risk of developing a second stone.](image)

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

**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.

<table>
<thead>
<tr>
<th>Serum</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>CO2</th>
<th>Creat</th>
<th>Ca</th>
<th>Mg</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/2/09</td>
<td>139</td>
<td>4.3</td>
<td>105</td>
<td>26</td>
<td>0.9</td>
<td>11.8</td>
<td>2.1</td>
<td>1.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urine</th>
<th>Vol24</th>
<th>Ca24</th>
<th>Ox24</th>
<th>Cit24</th>
<th>UpH</th>
<th>Cr24</th>
<th>Na24</th>
<th>UA24</th>
<th>CaOxSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/2/09</td>
<td>1.81</td>
<td>402</td>
<td>37</td>
<td>712</td>
<td>6.3</td>
<td>1700</td>
<td>134</td>
<td>0.64</td>
<td>8.2</td>
</tr>
<tr>
<td>Normal</td>
<td>2.00</td>
<td>&lt;250</td>
<td>20-40</td>
<td>&gt;450</td>
<td>5.8-6.2</td>
<td>50-150</td>
<td>&lt;0.80</td>
<td>4-6</td>
<td></td>
</tr>
</tbody>
</table>

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

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**Hypercalciuria: Thiazides & Stone Recurrence**

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

Curhan, NEJM 1993

**Hypercalciuria:** Recurrent Stones According to Diet

L Borghi, NEJM Jan 2002
Treatment of Risk Factors

Hyperoxaluria

Definition: Urine oxalate >45 mg/day

Treatment:
1. Urine Output >2 L
2. Diet low in oxalate, ascorbic acid
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.

<table>
<thead>
<tr>
<th>Serum</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>CO2</th>
<th>Creat</th>
<th>Ca</th>
<th>Mg</th>
<th>UA</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/6/02</td>
<td>131</td>
<td>4.4</td>
<td>106</td>
<td>15</td>
<td>1.4</td>
<td>9.9</td>
<td>2.2</td>
<td>7.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urine</th>
<th>Vol 24</th>
<th>Ca24</th>
<th>Ox24</th>
<th>Cit24</th>
<th>UpH</th>
<th>Na24</th>
<th>Cr24</th>
<th>UA24</th>
<th>UASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/02</td>
<td>1.2</td>
<td>177</td>
<td>31</td>
<td>72</td>
<td>6.8</td>
<td>106</td>
<td>1632</td>
<td>0.599</td>
<td>0.8</td>
</tr>
<tr>
<td>12/04</td>
<td>1.02</td>
<td>144</td>
<td>30</td>
<td>82</td>
<td>6.5</td>
<td>117</td>
<td>1566</td>
<td>0.654</td>
<td>1.0</td>
</tr>
<tr>
<td>Normal</td>
<td>2.00</td>
<td>&lt;250</td>
<td>20-40</td>
<td>&gt;450</td>
<td>5.8-6.2</td>
<td>50-150</td>
<td>varies</td>
<td>&lt;0.800</td>
<td>0-1</td>
</tr>
</tbody>
</table>

Where is the problem?
What is the treatment?
# Treatment of Risk Factors

## Hypocitraturia

<table>
<thead>
<tr>
<th>Definition</th>
<th>Urine citrate &lt;350 mg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>1. Urine output &gt; 2 L/day</td>
</tr>
<tr>
<td></td>
<td>2. K Citrate 20 mEq TID</td>
</tr>
<tr>
<td></td>
<td>3. Normal protein diet</td>
</tr>
<tr>
<td></td>
<td>4. Sod Bicarbonate</td>
</tr>
<tr>
<td>Goal</td>
<td>Urine citrate &gt;350 mg/day</td>
</tr>
<tr>
<td></td>
<td>Normal plasma Bicarb</td>
</tr>
</tbody>
</table>

## Effect of K-Citrate on Stone Recurrence

![Graph showing the effect of K-Citrate on stone recurrence over time.](image)

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

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**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.

<table>
<thead>
<tr>
<th>Serum</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>CO2</th>
<th>Creat</th>
<th>Ca</th>
<th>Mg</th>
<th>UA</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/6/01</td>
<td>141</td>
<td>4.4</td>
<td>106</td>
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<td>2.2</td>
<td>7.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urine</th>
<th>Vol24</th>
<th>Ca24</th>
<th>UUN</th>
<th>Cit24</th>
<th>UPO4</th>
<th>Cr24</th>
<th>Na24</th>
<th>UA24</th>
<th>UASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/01</td>
<td>1.1</td>
<td>319</td>
<td>24</td>
<td>323</td>
<td>2401</td>
<td>253</td>
<td>1.50</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>7/01</td>
<td>1.0</td>
<td>298</td>
<td>26</td>
<td>212</td>
<td>2427</td>
<td>242</td>
<td>1.44</td>
<td>3.9</td>
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<tr>
<td>Normal</td>
<td>2.0</td>
<td>&lt;250</td>
<td>&gt;450</td>
<td>50-150</td>
<td>&lt;0.80</td>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Definition</th>
<th>Urine uric acid &gt;750 - 800 mg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect</td>
<td>Nucleation of CaOx on uric acid</td>
</tr>
<tr>
<td>Treatment</td>
<td>1. ↓ dietary purines</td>
</tr>
<tr>
<td></td>
<td>2. Alkaline urine pH ~ 6.5</td>
</tr>
<tr>
<td></td>
<td>(Solubility of uric acid - Acidic urine - 100 mg/L)</td>
</tr>
<tr>
<td></td>
<td>At pH 7 – 1600 mg/L</td>
</tr>
<tr>
<td></td>
<td>3. K Citrate</td>
</tr>
<tr>
<td></td>
<td>4. Allopurinol</td>
</tr>
<tr>
<td>Goal</td>
<td>Urine uric acid &lt; 750-800 mg/day</td>
</tr>
</tbody>
</table>

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**Allopurinol in Hyperuricosuric Ca Stone Formers**

[Graph showing efficacy of Allopurinol vs Placebo over months of followup]

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 a common disease causing a fair amount of morbidity and 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.