Stone Doses and ER

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Disclosures

• Grant support from GE Health Care
Clinical Perspective

- Urolithiasis has a life time risk of 10-15%
- It has a high relapse rate (50% in 5-10 yrs and 75% in 20 yrs)
- Affects Men more than women
- Common clinical presentation – Acute flank pain and hematuria
<table>
<thead>
<tr>
<th>Stone Types</th>
<th>Composition</th>
<th>Occurrence</th>
<th>On KUB</th>
<th>On CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium oxalate monohydrate (COM) &amp; dehydrate (COD)</td>
<td>40-60%</td>
<td>Radio-opaque</td>
<td>Radio-opaque</td>
<td></td>
</tr>
<tr>
<td>Hydroxyapatite (Calcium phosphate)</td>
<td>20-60%</td>
<td>Radio-opaque</td>
<td>Radio-opaque</td>
<td></td>
</tr>
<tr>
<td>Brushite</td>
<td>2- 4%</td>
<td>Radio-opaque</td>
<td>Radio-opaque</td>
<td></td>
</tr>
<tr>
<td>Uric Acid</td>
<td>5-10%</td>
<td>Radio- lucent</td>
<td>Radio-opaque</td>
<td></td>
</tr>
<tr>
<td>Struvite</td>
<td>5-15%</td>
<td>Radio-opaque</td>
<td>Radio-opaque</td>
<td></td>
</tr>
<tr>
<td>Cystine</td>
<td>1- 2.5%</td>
<td>Mildly Opaque</td>
<td>Radio-opaque</td>
<td></td>
</tr>
</tbody>
</table>
Factors Influencing Treatment Decision

Urologic intervention is influenced by 3 crucial factors

- Stone size
- Stone Composition
- Patient Symptoms

Presence of obstruction is not the primary factor considered for urologic intervention.
MDCT in Urolithiasis

- Unenhanced CT - Initial investigation of choice in suspected urolithiasis

- Highly accurate test (Sensitivity = 95-98% & Specificity =96-100%)

- Allows accurate determination of stone size and composition

- Detects other causes of acute flank pain

- Reveals associated abnormalities like congenital abnormalities, infections and neoplasms
MDCT Technique

• **Scan Coverage** - Upper pole of kidneys to the base of the bladder

• **Patient preparation** - Bladder distension to visualize stones within the distal ureter

  **Slice thickness** – 2-5mm  
  **Pitch** - 1 - 1.6

**Coronal Reformations**  
(2.5 - 3mm)
Urolithiasis - CT Diagnostic Signs

Virtually all stones are radio-opaque on CT (>200HU)

Primary sign of Ureterolithiasis
Stone in the ureter with proximal hydroureter

Stones radiolucent on CT - Pure matrix stones and stones made of pure Indinavir (Indinavir - Protease inhibitor used in the treatment of HIV)
Value of Coronal Reformations

• Improved detection of stones unrecognized on axial images
• Improved detection of small ureteral and renal calculi at poles
• Enhances radiologist confidence.
• Differentiates phleboliths and calcified vascular plaques from urinary stones.
• Benefits the practicing urologists who are accustomed to visualizing the urinary tract in coronal view
Stone Burden Assessment

- Stone burden (stone size and volume) determines the type of procedure
- **ESWL or Ureteroscopy is performed for stones <1cm**
- **PCNL for stones >1.5cm**

Stone Size

- Accurate stone size measurement is paramount to plan treatment options
- The ideal method for accurate measurement on CT is to measure using **bone window settings (1250 X 250) and magnification**
Stones > 6mm & <15mm or smaller stone not responding to conservative treatment

- Medical Expulsive therapy (Alpha blockers)
  Intervene for unremitting pain, nausea, fever, failure to passage on medical therapy

Stones > 6mm & <15mm or smaller stone not responding to conservative treatment

- Extracorporeal Shockwave lithotripsy (ESWL)
- Ureteroscopic lithotripsy

Stone >15mm or Staghorn Calculi

- Percutaneous Nephrolithotomy (PCNL)
Stone Volumetry

Threshold based CAD Algorithms or manual semi-automated methods

- Linear measurement not suitable in irregularly contoured stones like stag horn calculi
- Measuring the stone volume eliminates this problem
- Total stone volume is an appropriate measure of stone burden
Stone Composition & Treatment Decisions

- **<400 HU**
  - Uric Acid Stone
  - Medical Management
    - Allopurinol
    - Treatment of Hyperuricemia

- **> 500 HU**
  - <1000 HU
    - (Struvite)
    - ESWL
  - >1000 HU
    - (Brushite, Cystine, COM)
    - Ureteroscopy
    - PCNL
MDCT and Stone Composition

Stone composition is determined either using HU values on MDCT or on Dual-energy CT

<table>
<thead>
<tr>
<th>Stone Composition</th>
<th>Attenuation value at 120kVp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uric Acid</td>
<td>200-450 HU</td>
</tr>
<tr>
<td>Struvite</td>
<td>600-900 HU</td>
</tr>
<tr>
<td>Cystine</td>
<td>600-1100 HU</td>
</tr>
<tr>
<td>Calcium Phosphate</td>
<td>1200-1600 HU</td>
</tr>
<tr>
<td>COM and Brushite</td>
<td>1700-2800 HU</td>
</tr>
</tbody>
</table>

• Stone composition also affects the efficacy of ESWL (Brushite, cystine and COM stones are hard and resistant, while struvite stones usually fragment easily)
Spectral Imaging for Stone Composition: Dual Source CT

• Dual Source CT can discriminate uric acid stone from other stone types

• Dual source CT is a 64 slice CT with two X-ray tubes and two detector assembly mounted onto a gantry with an angle of 90 degrees.

• By operating the two tubes at different energies (80 & 140 kVp) it is effective in tissue material characterization.
### Dual Source CT - Uric Acid vs Non Uric acid

<table>
<thead>
<tr>
<th></th>
<th>Uric Acid Stone</th>
<th>Non uric acid stone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element composition</strong></td>
<td>Light Elements</td>
<td>Heavy Elements</td>
</tr>
<tr>
<td>(H, C, N, O)</td>
<td>(P, Ca, S)</td>
<td></td>
</tr>
<tr>
<td><strong>Attenuation at 80 kVp</strong></td>
<td>Lower HU</td>
<td>Higher HU</td>
</tr>
<tr>
<td><strong>Attenuation at 140 kVp</strong></td>
<td>Higher HU</td>
<td>Lower HU</td>
</tr>
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</table>

**Example Attenuation Values**

- **80kV**
  - Calcium: 710 HU
  - Uric Acid: 290 HU

- **140kV**
  - Calcium: 480 HU
  - Uric Acid: 315 HU
Color Coding for Stones on Dual Source CT

- The post processing software algorithm assumes a mixture of water, calcium and uric acid for every voxel.
- Those voxels with dual energy (DE) behavior are color coded.
- Voxels with DE similar to Ca++ are coded Blue.
- Voxels with DE similar to uric acid are coded Red.
- Voxels with linear density at both kV remain Grey.
IMPROVED CHARACTERIZATION
Renal stones

Stone composition with SSDE CT
Role of dual energy CT in determination of stone composition

Figure 1

Figure 2

Figure 3

$Z = 14.73$
Clinical history

- 36 yo female with a history of stones. Underwent cystoscopy, right retrograde, right ureteroscopy, right laser lithotripsy, right ureteral stent placement, stone retrieval (In Jan 2008).
- Past Surgical History: Open pyelolithotomy - right side 10 years ago, ureteroscopy x2.

Stone analysis (Jan 2007): calcium oxalate monohydrate 100%
Spectral attenuation curve of different stone fragments
Spectral CT: Technique

**Step I:** Scout film

**Step II:** Non contrast low dose Stone protocol MDCT using a single source

**Step III:** Localization of the stone and focal dual energy acquisition of the anatomical region containing the stone
Step IV: Post processing of dual energy data using 3 material decomposition algorithm to obtain the color coded image.
Stone Fragility in Guiding Treatment

- CT helps predict stone fragility and susceptibility to lithotripsy.
- Stones which are heterogeneous are more fragile than homogenous stones which are more resistant to ESWL.
Stone Precursor-Randall’s Plaque

- **Randall’s Plaque** - Calcium salt deposits in the tip of renal papilla of patients with nephrolithiasis and are potential sites for calculus formation.
- These stone bearing papillae appear denser on non-contrast CT and represent Randall’s plaque on endoscopy.
- MDCT can help select patients at high-risk for stone formation, who may undergo appropriate medical management to halt the formation of stones.

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<table>
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<th>30 HU</th>
<th>Normal papillae</th>
</tr>
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<tr>
<td>58 HU</td>
<td>Whitish deposits - Randall’s plaque</td>
</tr>
</tbody>
</table>

| 58 HU | Stone bearing papillae |
Calculi with attenuation > 300 HU are radio-opaque & are followed up by **Abdominal Radiograph**

Calculi with attenuation < 200 HU are radiolucent & hence followed up by **CT**
Stone Follow up - Post Intervention

Pre Treatment

Post Treatment

Significant Stone Burden

Residual Stone Burden though significantly reduced

Significant stone burden necessitates further treatment
Differentiation between stent and stone is vital in post surgical follow up.

Stents and stones have the same CT appearance on abdominal window.

Bone window allows visual distinction between the stent and the stone which is accounted for by differences in pixel density.
MDCT in Planning Intervention

• Simple trigonometry on CT of the patients with complex stones could help endourologists in planning renal access.

• CT also helps in planning surgical interventions by identifying the location of the posterior calyx thus guiding fluoroscopic procedures like percutaneous nephrolithotomy
MDCT and Radiation Dose

- A key concern for repeated CT examinations in recurrent stone disease.

- The **effective radiation dose** during unenhanced CT
  
  2.8 to 13.1 mSv for men / 4.5 to 18 mSv for women

- Techniques for **Reduction of Radiation dose**
  
  - **Limit scanning area** (not typical Abd+Pelvis exam)
  
  - Increase in axial **slice thickness to 5mm** from 1-3 mm
    and include **2.5-3 mm coronal** reconstructions

  - **Lower dose CT exam** (noise index, kVp, pitch)
Strategies for Dose Reduction - Coverage Area

- From top of diaphragm to lower border of pubic symphysis
- From Top of kidneys to base of urinary bladder

Restrict Scanning Area

Dose Reduction by 15-20%

Targeted scans focused to area of interest can be performed for follow up CT exams
Strategies for Dose Reduction - Slice Thickness

Increase Slice thickness from 1-3mm to 5mm and include 2.5-3mm Coronal Reformations

Dose Reduction by 20-40%
Strategies for Dose Reduction
Role of Low kVp - Exam based on Body Weight

Dose = \sqrt{kVp}

140 kV (> 250 lbs)
120 kV (141-249 lbs)
100/80 kV (<140 lbs)

20% reduction
20% reduction
20% reduction

Total 40% Dose Reduction
Strategies for Dose Reduction - Increase in Noise Index/reference mAs (100-180)

- Noise Index -15
- Noise Index -20
- Noise Index -30

15-20% reduction
15-20% reduction

Total 30-40% Dose Reduction
Strategies for Dose Reduction

- **Limit Scanning area**
- **Increase slice thickness** Include coronal reformations
- **Low kVp**
- **Increase Noise Index**

**Total Dose Reduction by 40-70% from Standard dose**

DLP 1000 mGy-cm + Increase slice thickness Include coronal reformations + Low kVp + Increase Noise Index

DLP 200 mGy-cm
Adaptive Statistical Iterative Reconstruction (ASIR)

- Noise reduction reconstruction method to improve the signal-to-noise
- Relies on the accurate modeling of the distribution of noise in the acquired data

- MGH Experience (GE HD 750) 24 patients studied so far
  - Radiation dose reduction achieved (38-81%)

Kole et al 2006 Phys Med Biol
Current Imaging Strategy

The scope of imaging has extended beyond the mere detection of stone and its location.

The current strategy is to determine the stone composition, its fragility and quantification which has great implications in treatment planning.
Summary Points

• MDCT with multiplanar reformations is accurate in stone assessment

• The qualitative assessment by CT influences management by dictating treatment options like ESWL.

• Spectral imaging and CAD is emerging for stone composition/Quantitation

• Various strategies for radiation dose reduction in imaging of urolithiasis achieving accurate diagnosis and reduced radiation dose delivery.

• New reconstruction algorithms (ASIR) is promising in dose reduction
References