Neither I nor immediate family members have a financial relationship with a commercial organization that may have a direct or indirect interest in the content.
Background

- CT universally acknowledged to be most accurate imaging exam for stone detection, localization, and size determination
- But, for any one patient, multiple competing considerations in determining appropriate imaging
What Impacts Imaging Choice?

- Clinical setting (acute or not)
- Clinical certainty of stone disease
  - Need to detect alternative diagnoses
  - History of stone disease
- Concerns about radiation exposure
- Body habitus
Alternate Dx- Negative studies

- 55% “flank pain CT” had no stone disease\(^1\)
  - Up to 40% of studies are normal\(^2,3\)
- Range of 6-18\% \(^4,5\)
- Predict ureteral stone & decrease likelihood of alternate dx with STONE score\(^6\)

Questions

Are “flank pain” CT’s being used for appropriate indications?
Are reduced dose studies missing non-stone findings?

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Radiation exposure: What is “low dose?”

• “More meaning and less drama”

• No quantitative definition exists
  – Variable over time (hardware & software changes)
  – Geographical variability (regulation, body habitus)
  – Conceptual imprecision

• Ask the physicists, get many answers

• Stone CT: AUA definition 4 mSv, ACR ?3 mSv

1Bankier AA, Kressel HY. Radiology 2012;265:4-8.
How is radiation exposure reduced?

- Reduce coverage
  - Top of kidneys to bladder base
- Increase slice thickness, from 1-3mm → 5mm
  - Add coronal reformats
  - Save 30-50% dose

1Kambadakone AR. *RadioGraphics* 2010; 30:603–623
Dose reduction: Decrease tube current (mAs)

- Use automated dose modulation (esp. obese) (Mulkens TH. AJR 2007; 188:553–562)

Figure from Siemens.com
Decrease tube current (mAs)

<table>
<thead>
<tr>
<th>Tube current</th>
<th>Calculi (n=108)</th>
<th>All (n=108)</th>
<th>&gt;3mm (n=43)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>92%</td>
<td>92%</td>
<td>98%</td>
</tr>
<tr>
<td>50%</td>
<td>83%</td>
<td>83%</td>
<td>93%</td>
</tr>
<tr>
<td>25%</td>
<td>67%</td>
<td>67%</td>
<td>92%</td>
</tr>
</tbody>
</table>

- No significant differences 50% or 75% mAs reduction for detection of >3 mm stones
- Follow-up or in known stone formers

Ciaschini MW. *Radiology* 2009;251:105-111
mAs with Iterative Reconstruction

Mean reader Sensitivity

<table>
<thead>
<tr>
<th>Ref Std. Size</th>
<th>100% FBP Se</th>
<th>50% IR Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1 mm</td>
<td>71.4</td>
<td>69.9</td>
</tr>
<tr>
<td>2-3 mm</td>
<td>78.7</td>
<td>78.7</td>
</tr>
<tr>
<td>4-5 mm</td>
<td>69.7</td>
<td>72</td>
</tr>
<tr>
<td>6-7 mm</td>
<td>82.5</td>
<td>76.2</td>
</tr>
<tr>
<td>≥ 8 mm</td>
<td>89.3</td>
<td>90.7</td>
</tr>
</tbody>
</table>

- 50% exposure with IR not inferior to 100% FBP (p=0.001)
- Reader confidence similar (p =0.963)

Remer EM. Radiology 2014;272:749-756
Lower tube voltage (kVp)

- Improved contrast
- Dose decreased 35-75% (kVp 120 → 80)
- Image degradation (from noise)
- Weight-based kVp reduction
  - With ↑ patient size, higher-energy data is progressively important to maintain image quality

<table>
<thead>
<tr>
<th>Weight (lb.)</th>
<th>kVp</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;150</td>
<td>80-100 kVp</td>
</tr>
<tr>
<td>150-300</td>
<td>120 kVp</td>
</tr>
<tr>
<td>&gt;300</td>
<td>140 kVp</td>
</tr>
</tbody>
</table>

Reduced Exposure Accuracy

- Meta-analysis of 7 prospective studies
- <3 mSv
- Pooled sensitivity of 97%
- Pooled specificity of 95%

Prevalence of disease ~70%
Body habitus information not available
No U.S. papers (Germany, Canada, Switzerland, Korea)

Niemann T. AJR 2008;191:396-401
“Low Dose” usage

- 15 center STONE study; 8% <4mSv\(^1\)
- ACR dose registry (7/15-6/16)\(^2\)
  - Reduced dose (<3 mSv) on 8% of >100,000
  - Large variation in exposure both within and between facilities
  - Of ~1700 institutions in DIR, only 328 (20%) regularly performing stone specific CT

\(^1\)Smith-Bindman R. *JAMA Intern Med*. 2015;175:1413-6;
\(^2\)Weisenthal K. *Radiology* 2017 [epub before print]
Why don’t more sites modify CT protocols?

• It takes effort
  – Many ways to “skin a cat”
    • AEC, ↓mAs, ↓kVp, IR, collimation, weight-based
  – Approach different for different vendors
  – Many enterprises have multiple scanner models from different vendors

• Flank pain CT is used inexactely by some practitioners
  – ED need for patient disposition
Why don’t more sites modify CT protocols?

- Radiologist aren’t used to reduced dose images
  - There is a learning curve

Gandhi NS. *Radiology* 2016;280: 436
Reduced dose

10/17/17
DLP 200 3.5 mSv

2/20/09
DLP 400 6.5 mSV
Larger body habitus

4.8 mSv
Multidisciplinary Guidelines: Care Paths

When to image and how to image?
Example

• Goals
  – Minimize unnecessary imaging
  – Shared decision making
  – Facilitate prompt evaluation

• Algorithms for acute colic/known stone former & postoperative patient
Acute Colic

- Pain management
- Fluid resuscitation
- Lab evaluation
- Imaging
- Guidelines for Urology consult
- Counseling
- Discharge Instructions
### Variant 1: Suspicion of Stone Disease

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT abdomen and pelvis without IV contrast</td>
<td>8</td>
<td>Reduced-dose techniques are preferred.</td>
<td>🟣🌟🌟🌟🌟</td>
</tr>
<tr>
<td>CT abdomen and pelvis without and with IV contrast</td>
<td>6</td>
<td>This procedure is indicated if CT without contrast does not explain pain or reveals an abnormality that should be further assessed with contrast (e.g., stone versus phleboliths).</td>
<td>🟣🌟🌟🌟</td>
</tr>
<tr>
<td>US color Doppler kidneys and bladder retroperitoneal</td>
<td>6</td>
<td></td>
<td>O</td>
</tr>
</tbody>
</table>

### Variant 2: Recurrent Symptoms of Stone Disease

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>RRL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT abdomen and pelvis without IV contrast</td>
<td>7</td>
<td>Reduced-dose techniques are preferred.</td>
<td>🟣🌟🌟🌟🌟</td>
</tr>
<tr>
<td>US color Doppler kidneys and bladder retroperitoneal</td>
<td>7</td>
<td>This procedure is indicated in an emergent setting for acute management to evaluate for hydronephrosis. For planning and intervention, US is generally not adequate and CT is complementary as CT more accurately characterizes stone size and location.</td>
<td>O</td>
</tr>
<tr>
<td>CT abdomen and pelvis without and with IV contrast</td>
<td>6</td>
<td>This procedure is indicated if CT without contrast does not explain pain or reveals an abnormality that should be further assessed with contrast (e.g., stone versus phleboliths).</td>
<td>🟣🌟🌟🌟</td>
</tr>
<tr>
<td>X-ray abdomen and pelvis (KUB)</td>
<td>5</td>
<td>This procedure can be performed with US as an alternative to NCCT.</td>
<td>🟢🌟</td>
</tr>
</tbody>
</table>

- Evidence-based
- Mandated by CMS

Moreno CC. Acsearch.acr.org/docs/69362/narrative. Accessed 6/10/16
Detection of alternative findings

- Stones are high contrast objects
- Soft tissue abnormalities are low contrast
  - 52 patients with extraurinary findings,* no difference in reporting ($P = .215$)
  - 9 patients with potentially important findings, reduced dose significantly lower ($P = .024$)

*CRADS reporting system.
Zalis ME. Radiology 2005; 236:3–9
Conclusions

• Radiologists need to do better in adopting reduced exposure CT
• Acceptable exposure reduction level should be better defined
• Guidelines/ best practices for acute colic are needed
  – Identify situations where alternatives to CT are appropriate