Five Quick Tricks to Cut CT Patient Radiation Dose by 40%

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Conflict of Interest Statement

• I administer a grant from GE Healthcare which supports clinical investigation of cardiac CT.

• No support for equipment or salaries
CT Growth

Annual growth of >10% per year

No. of procedures (millions)

Total procedures (millions)


18.3 19.5 21.0 22.6 25.1 26.3 30.6 34.9 39.6 45.4 50.1 53.9 57.6 62.0

2.2 2.3 2.6 2.9 3.5 3.5 4.8 5.9 6.5 7.5 8.7 9.6 10.4 11

IMV Benchmark Report on CT, 2006
Relative Risk from a CT

- **To individual:**
  - Lifetime risk of cancer: **25%** (1 in 4)
  - Added risk: **0.05%** (1 in 1000 - 2000)

- **To population:**
  - 62M CT scans year in USA
  - Without CT: **13.778M** will die of cancer
  - With CT: **13.809M** will die of cancer
    - (additional 31K)
Five Quick Tricks to Cut CT Patient Radiation Dose by 40%

1. Center the Patient in the Gantry
Dose Reduction Techniques: Filters

The **bow-tie filter**: graphite that sits between the X-ray tube and patient

Results in reduction in CT dose.
### Patient Centering: Dose in ATCM

<table>
<thead>
<tr>
<th>SD</th>
<th>noise inc.</th>
<th>mA boost</th>
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<tbody>
<tr>
<td>Cent’d 6.47</td>
<td>0 %</td>
<td>0%</td>
</tr>
<tr>
<td>4 cm</td>
<td>8.40</td>
<td>30%</td>
</tr>
<tr>
<td>6 cm</td>
<td>9.22</td>
<td>43%</td>
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</tbody>
</table>

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*Courtesy of Joel Platt*
Patient Centering: Dose in ATCM

Hint: Carefully match bowtie filter size choice (small, medium, large) to patient size as determined from scout images
Five Quick Tricks to Cut CT Patient Radiation Dose by 40%

2. Externally Applied Shields
Externally Applied Shields

- Breast
- Gonadal (males)
- Thyroid
Breast Shield

- Bismuth shield
- Decreases breast dose
  - Up to 40% ( ! )
• Controversy !!

• Alternative: decide how much noise you can tolerate in the central mediastinum and cut mA to reach that noise level.
Breast Shield

- Increased noise in ant. chest
- Proper positioning:
  - Slight stand off from chest (blanket)
- All females age 12 - 50
Gonadal Shield
Thyroid Shield
40% reduction in breast dose
Five Quick Tricks to Cut CT Patient Radiation Dose by 40%

3. Control Scan Z Axis Length
Control Z-Axis

- Z-axis length creep

- “Throw in” a chest or pelvis
Control Z Axis: Shrink to Fit Pt.

• Challenge all technologists

• Control patient breathing and moving

• Especially avoid breast or pelvis
Control Z Axis: Shrink to Fit Pt.

• The Numbers:
  • 3 – 5% reduction in patient radiation dose per cm. of Z axis eliminated.

• Cut off 5 cm, reduce dose 15 – 25%
Minimize Number of Phases Used

- Limit to only needed:
  - 4 phase liver vs. 3 phase

- Use new protocols:
  - CTU – split bolus
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4. Adjust ACTM (noise index) and kVp to Body Size
Dose and mA

- **Linear relationship**

- Decrease mA to reduce dose linearly
Angular Tube Current Modulation

- Tube current is adjusted to minimize dose in lower density profiles of the patients.
- Occurs during each tube rotation.
Longitudinal Tube Current Modulation

- Varies the tube current (mA) along the z-axis
- Different mA applied to different regions
- Scout used to calculate mA along z-axis to yield a predetermined setting for image quality (Noise Index).
Combined Dose Modulation

Dose too high with fixed mA
Dose too low with fixed mA

Tube current (mA)

z axis of scan

M. Gunn – UW
Image Quality: Noise

- **Noise index (NI)**
  - Standard deviation of CT numbers within a ROI in a water phantom
- **Vendor specific term**
- **Typical NI:** 10 - 20
- **High NI (low dose):** 30 - 40
Noise Index $\propto \frac{1}{\sqrt{\text{Dose}}}$
Development of a Noise Index Table Demonstrating Interrelationships Among Noise Level, Reconstruction Slice Thickness, and Radiation Dose in 64-slice CT

Kalpana M. Kanal, PhD, Brent K. Stewart, PhD, Orpheus Kolokythas MD, William P. Shuman, MD

Department of Radiology
University of Washington
Seattle, Washington
AJR, 2007
<table>
<thead>
<tr>
<th>Reconstruction Slice Thickness (mm)</th>
<th>0.625</th>
<th>1.25</th>
<th>2.5</th>
<th>3.75</th>
<th>5</th>
<th>Relative Dose</th>
<th>% Dose Difference</th>
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<td>NI</td>
<td>NI</td>
<td>NI</td>
<td>NI</td>
<td>NI</td>
<td>NI</td>
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<tr>
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<td>11.42</td>
<td>9.01</td>
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<td>20.53</td>
<td>17.35</td>
<td>12.02</td>
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<td>7.85</td>
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<td>18.27</td>
<td>12.65</td>
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<td>22.75</td>
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<td>14.02</td>
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<td>26.54</td>
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<td>15.54</td>
<td>12.26</td>
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<td>18.12</td>
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<td>34.30</td>
<td>28.98</td>
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<td>36.10</td>
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<td>38.00</td>
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<td>22.25</td>
<td>17.56</td>
<td>14.54</td>
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<td>1.108</td>
<td>10.8%</td>
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<tr>
<td><strong>40.00</strong></td>
<td><strong>33.80</strong></td>
<td><strong>23.42</strong></td>
<td><strong>18.48</strong></td>
<td><strong>15.30</strong></td>
<td><strong>1.000</strong></td>
<td><strong>1.000</strong></td>
<td><strong>0.0%</strong></td>
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<tr>
<td>42.00</td>
<td>35.49</td>
<td>24.59</td>
<td>19.41</td>
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<td>0.907</td>
<td>-9.3%</td>
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<td>44.10</td>
<td>37.27</td>
<td>25.82</td>
<td>20.38</td>
<td>16.87</td>
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<td>0.823</td>
<td>-17.7%</td>
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<tr>
<td>46.31</td>
<td>39.13</td>
<td>27.11</td>
<td>21.40</td>
<td>17.71</td>
<td></td>
<td>0.746</td>
<td>-25.4%</td>
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<tr>
<td>48.62</td>
<td>41.09</td>
<td>28.47</td>
<td>22.47</td>
<td>18.60</td>
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<td>0.677</td>
<td>-32.3%</td>
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<tr>
<td>50.00</td>
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<td>30.65</td>
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<tr>
<td>52.00</td>
<td>45.30</td>
<td>32.78</td>
<td>24.97</td>
<td>20.51</td>
<td></td>
<td>0.557</td>
<td>-44.3%</td>
</tr>
</tbody>
</table>
ASIR and U Wa

- **Routine Body Imaging**
  - **Current:**
    - **Small:** FOV < 34 (BMI < 25)
      - NI 30, ASIR 40%
    - **Medium:** FOV 34 – 44 (BMI 25 – 35)
      - NI 36, ASIR 40%
    - **Large:** FOV > 44 (BMI > 35)
      - NI 40, ASIR 40%
kVp and Dose

- kVp → *exponential* impact on dose
  - 120 to 100 kV → 43% decrease in dose
  - 120 to 80 kV → 70% decrease in dose
- Variable: patient size/density
Same Patient, Different kVp

120 kVp
CTDI$_{vol}$ = 419

100 kVp
CTDI$_{vol}$ = 362
100 kV Scanning: Small Patients

- Decreases dose 43%
- BMI < 25, weight < 160 lbs.
- May need to increase mA or decrease NI
140 kVp Scanning: Large Patients?

- Very high dose
- Use only in unusual cases
  - Techs must get radiologist’s permission to use 140 kVp

50 mSv!
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5. Iterative Reconstruction
Noise Limits Dose Reduction

• **Answer:**
  
  • find a different way to reconstruct low dose images so they look much less noisy
ASIR : Different Assumptions

FBP
- Point Focal Spot
- Point Detector
- Point Voxel
- Pencil Beam
- Perfect Sample
- Line Integral
- Simple Calculation

ASIR
- Real Focal Spot
- Real Detector
- Cubic Voxel
- Broad Beam
- Statistical Model
- Physics Model
- Complex Computation

Simplicity ➔ Image Quality

A Better Model of Reality !
ASiR

- ASiR is more computationally intensive
- With today’s faster processors:
  - Increased time not noticeable
  - 10 images per sec. vs. 15 (FBP)
Low Contrast Detectability

- 50% ASiR at half dose = full dose FBP.

Full dose: 25.08mGy
Half dose: 12.42mGy
Impact of 30% ASIR

40% dose reduction
Which Is the ASIR Image: 40% Lower Dose?
Volume ASIR: Nice 3D
120 kVp, variable mAs (NI=36), 1.375 pitch. 0.625mm, BMI = 34
## Easy Low Dose Options

<table>
<thead>
<tr>
<th>Type</th>
<th>Dose Reduction</th>
<th>Benefits</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Habitus Dose Modulation (mA)</td>
<td>16-26%</td>
<td>Easy</td>
<td>Not automated</td>
</tr>
<tr>
<td>Tube current modulation (kVp)</td>
<td>53% (100 kVp) 88% (80 kVp)</td>
<td>Easy</td>
<td>Noise</td>
</tr>
<tr>
<td>External Shields</td>
<td>Up to 40% locally</td>
<td>Easy</td>
<td>Noise, artifact</td>
</tr>
<tr>
<td>Z-axis reduction</td>
<td>3-5% for 1 cm</td>
<td>Easy</td>
<td>Missed structures</td>
</tr>
<tr>
<td>Patient Centering</td>
<td>5-30%</td>
<td>Easy</td>
<td>Every pt. every time</td>
</tr>
<tr>
<td>Iterative reconstruction</td>
<td>30-45%</td>
<td>Automatic</td>
<td>Availability Processing time</td>
</tr>
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</table>