BODY CT: WHAT IS A GOOD CT EXAM?

Mannudeep K. Kalra, MD

Webster Center for Advanced Research and Education in Radiation
Massachusetts General Hospital and Harvard Medical School
Financial Disclosures

- RSNA Educational Scholar Grant 2010-13
- Research grant from GE Healthcare and Siemens Medical Solutions
- Medical Advisory Board, GE Healthcare
Body CT: What is a good CT exam?

- Is not the lowest dose CT the best CT exam?
- Can I really see everything on lowest dose CT?

- I can see many things on many low dose CT exams
  - Good exams
- But I can not see somethings on some low dose CT
  - Bad exams
- Not all low dose CT are good CT exams!? Damn!
  - Some times they are good! Some times they are bad!
Little noise: High “Quality”

Lesion Detection – high confidence

High radiation dose

Not Good

Pediatric patients
Benign (stones)
Follow up CT
Lungs
Bones

Good

Advanced or aggressive malignancy
Good CT? Liver Lesions Low contrast

50 mAs
2.6 mGy
FBP 5mm
Great CT!
Liver Lesions
Low contrast
Some noise

Lesion Detection – high confidence

Lower radiation dose

Not Good

Pediatric patients
Follow up CT
Lungs
Bones
Stones
Ca++

Good

General “rule out” abdominal CT
Known cancer
High noise

Lesion Detection – high confidence

Low to very low radiation dose

Not Good

Rule out Abdo CT
Low contrast lesions

Good

Pediatric patients
Follow up CT SCREENING
Bones
Kidney stones
180 mAs
9 mGy
5mm FBP

Good CT?
Kidney stones
High Contrast
CTA, Ca++
40 mAs
1.4 mGy
5mm FBP

Good CT!!
Kidney stones
High Contrast

CTA, Ca++
Good CT for lung cancer screening

150 mAs  110 mAs

75 mAs  40 mAs  1.4 mGy
chest CT at various tube current levels

- Pleural effusion
- Collapsed lung

<table>
<thead>
<tr>
<th>Tube Current</th>
<th>mA</th>
<th>Effective Dose</th>
<th>mGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>540 mA</td>
<td>8.5 mSv</td>
<td>2.6 mGy</td>
<td></td>
</tr>
<tr>
<td>270 mA</td>
<td>4.2 mSv</td>
<td>1.3 mGy</td>
<td></td>
</tr>
<tr>
<td>135 mA</td>
<td>2.1 mSv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72 mA</td>
<td>1.1 mSv</td>
<td>2.6 mGy</td>
<td></td>
</tr>
<tr>
<td>36 mA</td>
<td>0.5 mSv</td>
<td>1.3 mGy</td>
<td></td>
</tr>
</tbody>
</table>

kVp: 120
5mm
What is a Good body CT Exam?

- Justified: Ensuring that CT is the right test
- Interpretable: Tailoring CT for specific indications
- ALARA: Adapting Dose to patient size or age
Characters of Good CT exam

- Appropriate scan indication
- Lack of motion artifacts: Movements, Breathing
- IV access with contrast injection technique
- Appropriate localizer radiographs: Coverage: AEC
- Transverse CT images
  - Scan range
  - # Scan series
  - Scan parameters
Attributes of Good Body CT

- Indication based scan protocols for each body region

### Chest CT
- Routine chest
- CT PE
- Lung nodule FU
- Cancer screening
- Diffuse lung Dz
- Tracheal protocol

### Abdominal CT
- Routine abdomen
- Kidney stone
- CT colonography
- CT urography
- Dual phase liver
- CT enterography
Good CT requires Good Instructions

- **Aim:** To minimize wasteful repeats from motion
- **Emphasize when practical**
  - Please do not move during CT exam unless Emergent
  - Demonstrate breathing or breath hold instructions

- **Know what to do when patient can not co-operate**
  - Change protocol: Faster scanning or Faster scanner
  - Different scanner:
    - Broader (> = 64 MDCT)
    - Faster (high pitch, speed, or DSCT)
Contrast Injection Technique

- **Aim:**
  - Minimize repeats from poor contrast
  - Have good CNR esp. CT angiography

- **Good CNR also implies greater tolerance to low dose**
  - Good “specified” IV access
  - Contrast type, injection rate, and volume
  - Contrast-to-scan delay: Prefer bolus testing or tracking
Good CT Localizers

Localizer Radiograph

Remember good “centering” = good AEC and quality
Reduce dose for localizer radiograph
  – 80 kVp
  – Lower mA (20-40 sufficient)
  – Localizer with good centering requisite for AEC
Good CT Exam: Scanning protocols

- After Indications, adapt Dose to Patient Size
  - Tube Current:
    - Prefer AEC over fixed mA for most body CT
    - Some AEC techniques need adjustment to size
    - Can use fixed mA for very low dose CT protocols
    - Some AEC techniques require adjustment for weight
  - Kilovoltage selection: Automated or user-determined
- Pitch: Except for DSCT, specific desired quality
Good CT Exam: Scanning protocols

- Scan series
  - Must be minimum required
  - When multiple-dose should not be multiple folds higher
- Scan length: Targeted and focused
- Beam collimation: Per slice thickness and scan length
- Fast gantry rotation speed to minimize motion
- Reconstruction kernel
  - Softer: thinner slices (cardiac CT or CTA) or lower dose
  - Sharper: Bones and Lungs
# Good CT Exam: Notification Values

<table>
<thead>
<tr>
<th>CT Scan Region</th>
<th>CTDIvol Notification Value (mGy)</th>
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</thead>
<tbody>
<tr>
<td>Adult Head</td>
<td>80</td>
</tr>
<tr>
<td>Adult Torso</td>
<td>50</td>
</tr>
<tr>
<td>Pediatric Head</td>
<td></td>
</tr>
<tr>
<td>&lt;2 years old</td>
<td>50</td>
</tr>
<tr>
<td>2 – 5 years old</td>
<td>60</td>
</tr>
<tr>
<td>Pediatric Torso</td>
<td></td>
</tr>
<tr>
<td>&lt;10 years old (16-cm phantom)</td>
<td>25</td>
</tr>
<tr>
<td>&lt;10 years old (32-cm phantom)</td>
<td>10</td>
</tr>
<tr>
<td>Brain Perfusion</td>
<td></td>
</tr>
<tr>
<td>(examination that repeatedly scans the same anatomic level to measure the flow of contrast media through the anatomy)</td>
<td>600</td>
</tr>
<tr>
<td>Cardiac</td>
<td></td>
</tr>
<tr>
<td>Retrospectively gated (spiral)</td>
<td>150</td>
</tr>
<tr>
<td>Prospectively gated (sequential)</td>
<td>50</td>
</tr>
</tbody>
</table>
Good Body CT

- Chest CT doses < Abdomen CT doses
- Indication based dose reduction
  - Stone protocol < Routine or Rule out abdominal CT dose
  - Lung nodule < Routine or Rule out chest CT dose
- Smaller patient < Medium size < large patient doses
Good CT for Biopsy - Axial and Length

After lesion localization, reduce dose for CT guided Bx
- Axial acquisitions
- Reduce scan length and mA and kVp

Localizer images  Bx needle  Subsequent scans at 1-2 mGy

120 kV 250 mAs  100 kV 88 mAs

<table>
<thead>
<tr>
<th>Patient Position</th>
<th>Scan</th>
<th>KV</th>
<th>mAs / ref.</th>
<th>CTDIvol</th>
<th>DLP</th>
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<tbody>
<tr>
<td>Topogram</td>
<td>1</td>
<td>120</td>
<td>250 / 200</td>
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<tr>
<td>LOCALIZER</td>
<td>2</td>
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<td>236</td>
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<tr>
<td>Biopsy</td>
<td>4</td>
<td>100</td>
<td>236</td>
<td>3.77</td>
<td>27</td>
</tr>
<tr>
<td>Biopsy</td>
<td>5</td>
<td>100</td>
<td>236</td>
<td>3.98</td>
<td>11</td>
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<tr>
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<td>236</td>
<td>3.77</td>
<td>27</td>
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<td>100</td>
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<td>3.98</td>
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<td>100</td>
<td>99</td>
<td>3.84</td>
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<tr>
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<td>100</td>
<td>99</td>
<td>3.84</td>
<td>11</td>
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<td>100</td>
<td>96</td>
<td>3.84</td>
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<td>Biopsy</td>
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<td>100</td>
<td>99</td>
<td>3.98</td>
<td>11</td>
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<tr>
<td>Biopsy</td>
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<td>100</td>
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<td>3.98</td>
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<td>100</td>
<td>99</td>
<td>3.84</td>
<td>11</td>
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<tr>
<td>Biopsy</td>
<td>14</td>
<td>100</td>
<td>99</td>
<td>3.84</td>
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<td>99</td>
<td>3.84</td>
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<tr>
<td>Biopsy</td>
<td>16</td>
<td>100</td>
<td>99</td>
<td>3.84</td>
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<tr>
<td>Biopsy</td>
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<td>100</td>
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<td>Biopsy</td>
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<td>100</td>
<td>95</td>
<td>3.72</td>
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<td>95</td>
<td>3.72</td>
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<tr>
<td>Biopsy</td>
<td>20</td>
<td>100</td>
<td>95</td>
<td>3.72</td>
<td>11</td>
</tr>
</tbody>
</table>
Good CT: Limit scan length for Multi-pass CT

For multiple series exams

E.g. check for loculated effusions
  - Limit scan length, reduce kV and mA

Standard dose supine series:
  Entire chest, 120 kVp, 160 mAs

Low dose prone images:
  Small scan length, 80 kVp, 50 mAs (<1 mGy)
Good PE CT: shorter Scan Length

PE protocol
Apices to adrenal

PE protocol
Apices to lung bases

<table>
<thead>
<tr>
<th>Scan</th>
<th>kV</th>
<th>mAs / ref.</th>
<th>CTDMol</th>
<th>DLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topogram</td>
<td>1</td>
<td>120</td>
<td>12.13</td>
<td>12</td>
</tr>
<tr>
<td>PreMonitoring</td>
<td>2</td>
<td>120</td>
<td>60</td>
<td>12.13</td>
</tr>
<tr>
<td>I.V. Bolus</td>
<td>3</td>
<td>120</td>
<td>60</td>
<td>36.40</td>
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<tr>
<td>Monitoring</td>
<td>6</td>
<td>120</td>
<td>210 / 240</td>
<td>14.20</td>
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### Scan parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan coverage</td>
<td>Apices to adrenals</td>
</tr>
<tr>
<td>Mode</td>
<td>Helical</td>
</tr>
<tr>
<td>Time</td>
<td>0.5 second</td>
</tr>
<tr>
<td>Recon. thickness</td>
<td>2.5 mm</td>
</tr>
<tr>
<td>Detector collimation</td>
<td>64*0.625 mm</td>
</tr>
<tr>
<td>Pitch</td>
<td>0.984:1</td>
</tr>
<tr>
<td>Speed</td>
<td>40 mm/rotation</td>
</tr>
<tr>
<td>KVp</td>
<td>120</td>
</tr>
<tr>
<td>Recon. kernel</td>
<td>FBP or h-IRT</td>
</tr>
<tr>
<td>AEC settings</td>
<td></td>
</tr>
</tbody>
</table>

#### Mode

- **Helical**: Most CT
- **Axial**: Diffuse lung Dz
  - Prospective EKG triggering

#### KVp

- 120

#### Reconstruction kernel

- FBP or h-IRT
- AEC settings

### Scan Coverage

- **Prone AXIAL**: DLP = 43

### DLP Calculation

**Inspiration**

- Helical DLP = 419

**Expiration**

- AXIAL DLP = 86

**Total DLP**: 546 and ED 9.3 mSv

**Good CT**: Diffuse lung disease

*Helical vs Axial Mode*
Good CT for Lung findings: Low Dose

- 540 mA, 20.2 mGy
- 270 mA, 10.1 mGy
- 135 mA, 5 mGy
- 72 mA, 2.7 mGy
- 36 mA, 1.3 mGy
Good body CT: Low-dose kidney stone

Effective Dose: 1.5 mSv
66% reduction

Kalra et al. Radiology 2005
Low Dose CT Colonography

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector Configuration</td>
<td>64*0.625</td>
</tr>
<tr>
<td>Beam Pitch</td>
<td>1.35: 1</td>
</tr>
<tr>
<td>Table Speed (mm/rotation)</td>
<td>55</td>
</tr>
<tr>
<td>Gantry Rotation Time (second)</td>
<td>0.5</td>
</tr>
<tr>
<td>Tube Potential (kVp)</td>
<td>120</td>
</tr>
<tr>
<td>Tube Current (mA)</td>
<td>50 supine 100 prone</td>
</tr>
<tr>
<td>Slice Thick/Recon Interval (mm)</td>
<td>2.5/1.25</td>
</tr>
</tbody>
</table>

CT Colonography (100 mA, 120 kVp) in 78-kg woman demonstrates sessile polyp (arrow) in sigmoid colon
Filtered back projection

Advantages
- Faster reconstruction
- Less costly equipment

Disadvantages
- Higher image noise
- More streak artifacts as well as beam hardening
- Does not consider attenuation and scatter

Iterative Reconstruction tech.

Advantages:
- Lower image noise
- Reduce radiation dose
- Almost same recon time
- Considers scatter effect
- Computationally more accurate

Disadvantages:
- Need faster and robust computers
- Extra cost for upgrade
Types of iterative reconstructions

Available Techniques

- Adaptive Statistical Iterative Reconstruction (ASIR) (GE Healthcare)
- Iterative Reconstruction in Image Space (IRIS) (Siemens Healthcare)
- Model Based Iterative Reconstruction (MBIR) (GE Healthcare)
- Model Based Algebraic Iteration (MBAI) (© HH Pien, Mass General)
- iDose (Philips Medical Solutions)
- Adaptive Iterative dose reduction (AIDR) (Toshiba Medical Systems)
Abdominal CT acquired at 3 different radiation doses with informed consent. IRIS images were acceptable at 50 mAs but FBP images were unacceptable at 50 mAs.
Chest CT acquired at 3 different radiation doses with informed consent. IRIS images are superior to FBP at all mAs levels.
Good Body CT: How Do You Get it?

- Cynthia McCollough or Dianna Cody...

- Understand CTDI and DLP
- Compare CTDI and DLP with RDL (eg. ACR)
- Reduce if necessary: Small Steps – recognize effect
- Increase if necessary: Small Steps
- Stratify CT protocols per indications
- Each protocol with AEC or patient size modifications
Acknowledgement

Sarabjeet Singh, MD
Sanjay Saini, MD
Matthew D. Gilman, MD
Eugene Mark, MD
James Stone, MD

Contact information:
mkalra@partners.org

Thank you!