Strategies for Standardizing Image Quality and Patient Dose Across a Range of CT Scanner Models and Patient Sizes

Cynthia H. McCollough, PhD, DABR, FAAPM, FACP
Director, CT Clinical Innovation Center
Professor of Medical Physics and Biomedical Engineering
Mayo Clinic, Rochester, MN

DISCLOSURES

Research Support:

<table>
<thead>
<tr>
<th>NIH</th>
<th>Other</th>
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<tbody>
<tr>
<td>EB 017095</td>
<td>Mayo Discovery Translation Award</td>
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<tr>
<td>EB 017185</td>
<td>Mayo Center for Individualized Medicine Award</td>
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<tr>
<td>EB 016966</td>
<td>Thrasher Foundation</td>
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<tr>
<td>DK 100227</td>
<td>Siemens Healthcare</td>
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<tr>
<td>HR 046158</td>
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<td>RR 018898</td>
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Off Label Usage
None
Objectives

- To measure the image quality and dose for a routine abdomen scan protocol for each scanner model available to us in our large group practice
- To determine the consistency – or lack thereof - of image quality and dose so that action could be taken to deliver more consistent results across our practice
- To develop a strategy that could be broadly applied to standardize exam quality across diverse practices and CT scanners

Methods: Scanners

- 16 CT scanners
  - 13 models covering most models in our system
  - 3 manufacturers (GE, Siemens, Toshiba)
- Scanner locations
  - 3 scanners on main campus in Rochester
  - 13 scanners at 10 off-campus clinics and hospitals
Methods: Abdomen phantoms

- 15 year old = 24 cm lateral width
- Medium adult = 32.5 cm lateral width
- Large adult = 38.9 cm lateral width

Methods: Data collection

- Protocol:
  - Routine adult abdomen/pelvis scan protocol in use clinically at each practice (no previous standardization performed)
- Spatial resolution – in-plane (MTF):
  - Thin metal wire suspended in air: measures modulation transfer function
- Spatial resolution – z axis (SSP):
  - Thin Au foil embedded in acrylic: Measures section sensitivity profile
- Image noise and console-reported CTDI
  - 3 tissue equivalent abdomen phantoms
  - Assesses response of automatic exposure control to patient size
- CT tech instructed to scan each phantom as if it was a patient
Results: Protocol variations

<table>
<thead>
<tr>
<th>kv</th>
<th>Quality reference effective mAs</th>
<th>Noise Index or Std Dev</th>
<th>AEC variants</th>
<th>Recon</th>
<th>Image width</th>
</tr>
</thead>
</table>
| 80-130 | 150-240                         | 10-15                   | • Size-specific technique charts  
• Default settings  
• FBP  
• Iterative | 5 mm    |             |

Results: Phantom images

<table>
<thead>
<tr>
<th>Wire phantom</th>
<th>Foil phantom</th>
<th>Abdomen phantom (large adult)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire</td>
<td>Foil</td>
<td></td>
</tr>
</tbody>
</table>

50 mm FOV  50 mm FOV  400 mm FOV
Results: MTF

![MTF Graph](image)

<table>
<thead>
<tr>
<th>MTF Data</th>
<th>50% (lines/cm)</th>
<th>10% (lines/cm)</th>
<th>2% (lines/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.54</td>
<td>6.20</td>
<td>7.84</td>
</tr>
<tr>
<td>Std dev</td>
<td>0.37</td>
<td>0.34</td>
<td>0.70</td>
</tr>
<tr>
<td>min</td>
<td>2.84</td>
<td>5.81</td>
<td>7.11</td>
</tr>
<tr>
<td>max</td>
<td>4.10</td>
<td>7.19</td>
<td>10.13</td>
</tr>
<tr>
<td>B10</td>
<td>2.4</td>
<td>4.8</td>
<td>5.6</td>
</tr>
<tr>
<td>B30</td>
<td>3.2</td>
<td>5.6</td>
<td>7.2</td>
</tr>
<tr>
<td>B50</td>
<td>6.4</td>
<td>8.8</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Results: SSP

![SSP Graph](image)

<table>
<thead>
<tr>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.- Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWHM (mm)</td>
<td>5.4</td>
<td>0.6</td>
</tr>
</tbody>
</table>
**Results: Noise**

- LightSpeed 64 VCT
- BrightSpeed Elite 16
- LightSpeed 16
- BrightSpeed 16
- Discovery 750 HD
- LightSpeed 64 VCT
- Aquilion 64
- Aquilion 64
- Aquilion One
- Aquilion 16
- Aquilion 32
- Definition FLASH
- Sensation 64
- Sensation 16
- Emotion 16
- Sensation 64

**Results: CTDIvol**

<table>
<thead>
<tr>
<th></th>
<th>CTDI (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15 yr</td>
</tr>
<tr>
<td>Mean</td>
<td>10.1</td>
</tr>
<tr>
<td>Std Dev</td>
<td>6.1</td>
</tr>
<tr>
<td>Min</td>
<td>4.5</td>
</tr>
<tr>
<td>Max</td>
<td>23.5</td>
</tr>
</tbody>
</table>
Recommended standardization process

1. Establish target values and ranges for image noise and resolution

2. Standardize in-plane res.

- Recon. kernel

MTF
Recommended standardization process

1. Establish target values and ranges for image noise and resolution
2. Standardize in-plane res.

MTF
- Recon. kernel

SSP
- Slice thickness
- Recon. mode

1. Establish target values and ranges for image noise and resolution
2. Standardize in-plane res.
4. Standardize image noise

MTF
- Recon. kernel

SSP
- Slice thickness
- Recon. mode

Noise
- Adjust AEC settings
- Develop size-specific rules
**Recommended standardization process**

1. Establish target values and ranges for image noise and resolution
2. Standardize in-plane res.
4. Standardize image noise
5. Optimize dose

**Discussion (1)**

- In-plane resolution was relatively consistent among all scanners. The same kernel should be used for scanners of the same make.
- Image width was consistently higher for GE models, particularly when “Plus” mode was used.
- GE “Full” mode should be selected for better comparability to other scanner manufacturers.
- SSP impacts image noise and should be standardized prior to direct image noise manipulation.
**Discussion (2)**

- AEC behavior significantly affects noise and dose, and is the most important parameter to standardize.
- Size-dependent image noise measurements are essential for demonstrating AEC behavior and standardizing across patient size.
- Our practice deems it appropriate to let noise increase somewhat with increasing patient size.
- For AEC systems that work to maintain the same image noise, technique charts must be developed that vary the noise index / std. dev. values and mA limits.

**Discussion (3)**

- Iterative reconstruction changes everything!
- To a large degree
  - Dose and noise become uncoupled
  - Resolution and noise become uncoupled
- Low contrast resolution can be negatively affected even when MTF, SSP, and noise are all adequate
- We recommend using FBP to standardize, then turning on moderate levels of iterative recon and adjusting the dose downward by approximately 25% for low contrast tasks and 50% for high contrast tasks
Conclusions

• Three sets of measurements, evaluating spatial resolution and image noise, can be used to guide standardization efforts and improve image quality consistency across a diverse fleet of CT scanners