Translating Protocols Across Patient Size: Babies to Bariatric

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Disclosures

Research Support:

NIH:  EB 079861
      DK 083007
      DK 059933
      EB 004898
      RR 018898

Siemens Healthcare

Off Label Usage
None
Since no CT image looked “over-exposed,” the community lost the sense of needing to adjust the mAs or kVp for patient size, as was inherent to film/screen imaging.
FDA Public Health Notification:
Reducing Radiation Risk from Computed Tomography for Pediatric and Small Adult Patients

November 2, 2001

While the benefits of computed tomography are well known ... those benefits are not without risks.

... emphasize the importance of keeping radiation doses ... as low as reasonably achievable, especially for pediatric and small adult patients, who may sometimes receive more radiation than needed to obtain diagnostic images.

... stress the importance of adjusting CT scanner parameters appropriately for each individual’s weight and size, and for the anatomic region being scanned.
Dose management is about getting the right dose for the specific patient and the specific diagnostic task.

For large patients, this can indeed mean a dose* increase.

*Doubling the mAs on an obese patient to achieve the same image noise as standard patient results in only an approximately 30% increase in effective dose due to the extra layers of fat tissue “shielding” many of the sensitive internal organs.
“Right-sizing” the dose
mAs works - IF all else constant
Technique charts

- Adapt the scan parameters to
  - specific patient
  - specific diagnostic task
- Reduce dose for pediatric and small patients
- Improve image quality for large patients
- Ensure consistency across practice
  - dose and image quality
Exponential relationship between patient thickness, mAs, and measured photons

\[ N_0 = N \cdot \exp (0.693 \cdot \frac{t}{HVL}) \]

To achieve same image noise (N)
Estimating Patient Attenuation

- Lateral width (skin to skin) at the level of the liver
  - from the A/P CT radiograph
- For patients with very large upper chest or hips
  - use measurement from the level of the liver
  - If in doubt, go up up a size
- Reconstruction (display)
  FOV chosen as usual
  - may be different from the width used to determine mAs.

33 cm
## Generalized Technique Chart
*(fixed image thickness)*

### Abdomen & Pelvis technique for Adults

<table>
<thead>
<tr>
<th>Lateral patient width (cm)</th>
<th>mAs (relative to standard Adult protocol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.1 - 26</td>
<td>0.4</td>
</tr>
<tr>
<td>26.1 - 30</td>
<td>0.5</td>
</tr>
<tr>
<td>30.1 - 35</td>
<td>0.7</td>
</tr>
<tr>
<td>35.1 - 40</td>
<td>1.0</td>
</tr>
<tr>
<td>40.1 - 45</td>
<td>1.4*</td>
</tr>
<tr>
<td>45.1 - 50</td>
<td>2.0*</td>
</tr>
</tbody>
</table>
# Image Gently Protocol Recommendations

<table>
<thead>
<tr>
<th>PA Thickness (cm)</th>
<th>Approx Age</th>
<th>Abdomen mAs Reduction Factor (RF)</th>
<th>Thorax mAs Reduction Factor (RF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>newborn</td>
<td>0.43</td>
<td>0.42</td>
</tr>
<tr>
<td>12</td>
<td>1 yr</td>
<td>0.51</td>
<td>0.49</td>
</tr>
<tr>
<td>14</td>
<td>5 yr</td>
<td>0.59</td>
<td>0.57</td>
</tr>
<tr>
<td>16</td>
<td>10 yr</td>
<td>0.66</td>
<td>0.64</td>
</tr>
<tr>
<td>19</td>
<td>15 yr</td>
<td>0.76</td>
<td>0.73</td>
</tr>
<tr>
<td>22</td>
<td>small adult</td>
<td>0.90</td>
<td>0.82</td>
</tr>
<tr>
<td>25</td>
<td>med adult</td>
<td><strong>1.0</strong></td>
<td>0.91</td>
</tr>
<tr>
<td>31</td>
<td>large adult</td>
<td>1.27</td>
<td>1.16</td>
</tr>
</tbody>
</table>
Guiding principles

- All decisions made in the direction of conservative dose reduction
  - wanted no non-diagnostic exams
  - can iteratively reduce further as staff gain comfort
- Involve pediatric and adult radiologists and lead techs
- ER, inpatient and outpatient scans
- Get leadership buy-in
- Provide mandatory education with roll out
- Aim for consistency, staff must use chart
## Example

### Abd/Pelvis Technique Chart

<table>
<thead>
<tr>
<th>Primary image thickness (mm)</th>
<th>Mode (pitch)</th>
<th>Table speed (mm/rot)</th>
<th>Retro recon thickness available (mm)</th>
<th>Lateral patient width (cm)</th>
<th>mA (at 0.8s)</th>
<th>kVp (at 0.8s)</th>
<th>mA (at 0.5s)</th>
<th>kVp (at 0.5s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.75</td>
<td>HQ</td>
<td>7.5</td>
<td>2.5 5.0</td>
<td>up to 14</td>
<td>50</td>
<td>120</td>
<td>90</td>
<td>120</td>
</tr>
<tr>
<td>3.75</td>
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<td>7.5</td>
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<td>14.1 - 18</td>
<td>70</td>
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<td>120</td>
<td>190</td>
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Last modified: 12/09/01

* mA limit reached - use the 0.8 sec option unless otherwise indicated.
### Example

**Abd/Pelvis Technique Chart** (pediatric and adult)  
**Lightspeed (QX/i and Plus)**

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(last modified 12/09/01)
AEC: Automatic Exposure Control

- Radiographic – phototiming
- Fluroscopy - automatic brightness control
X-ray attenuation

- Varies over body region and with projection angle
- Image noise is primarily determined by noisiest projections (thick body parts)
- More photons (dose) to thinner body parts is unnecessary radiation dose
Three Levels of AEC

- For a single cross section, automatically adjust the mA along different directions
  - (x-y modulation)
- For a single patient, automatically adjust the mA for different body parts
  - (z modulation)
- For different patients, automatically adjust the mA based upon the patient size
  - “Right sizing” dose for each patient
Example: 6 year old child

Scanned with adult protocol
(but using AEC dose reduction strategy)

Quality reference eff. mAs = 165

Mean eff. mAs = 38
Routine Abd/Pelvis (5 mm)
Quality reference eff. mAs = 240
61 y.o. female
30 cm lateral width -> 120 eff. mAs
88 eff. mAs

122 eff. mAs
Routine Chest/Abdomen/Pelvis (5 mm)
Quality reference eff. mAs = 240
71 y.o. male
43 cm lateral width -> 340 eff. mAs

Sensation 16
Ex: CT20031125071453
Topogram 1.0 T20s
Se: 1/2
Im: 1/4
Cor: 1.0

512 x 512
T20s

Mag: 1.0x

120.0 kV
35.0 mA
Routine Abdomen/Pelvis (5 mm)
Quality reference eff. mAs = 240

51 y.o. male
48 cm lateral width ->350 eff. mAs @ 140 kVp
What to do when you see this (or similar)

Scan Controller

Peak exposure demand exceeds system limit. Locally increased image noise may result.

You may
- increase the kV
- increase the Rotation time
- decrease Pitch

Load  Cancel
Don’t proceed until you try ...

- Decrease the pitch (gives same effective mAs with less mA, may be within limits)
  - Increases scan time, which may invoke other tube loading limits, so make sure CTDIvol doesn’t start to drop
- Use wider collimation
  - Decreases scan time again
  - Limits thinnest images that you can reconstruct
- Increase kV
  - Decreases iodine contrast
  - MUST change threshold for bolus tracking trigger (& W/L)
  - Must set a new target mA value (e.g. quality reference mAs)
Don’t proceed until you try ...

- Increase rotation time
  - Increases scan time
  - Can affect contrast media timing

-AND-

- Be sure to make sure timing and image thickness trade-offs are acceptable for the exam type (e.g. angiography)

- Thicker image width and smoother reconstruction kernels may be needed

- Use extended FOV option if available
  (minimizes truncation artifacts – streaks and white regions at edge of FOV)
Effective mAs decreases relative to our technique charts

- Exam average: 21.0%
- Upper lung: 29.7%
- Breast: 54.8%
- Liver: 13.2%
- Pelvis: 23.2%
Eff. mAs decreases relative to a single eff. mAs value (i.e. no technique charts)

- Average of all patients 18.5%
- Slim patients 44.9%
- Large patients 3.1%
Automatic exposure control

• Analogous to photo-timing
• User determines IQ (noise) requirements (hard)
  – don’t need “pretty” pictures for all diagnostic tasks
  – need to choose low noise, standard, or low dose dependent on the diagnostic task
• System determines the right mAs (easy)
• Will adjust mA
  – during rotation (x,y)
  – along z-direction
  – x, y and z
IQ (noise) Selection Paradigms

• GE: Noise Index
  – Referenced to std. deviation of pixel values in a water phantom
  – mA per rotation calculated based on Scout
  – Tries to maintain constant noise over all images

• Philips: Reference Image
  – Automatic Current Setting (ACS)
  – Save an acceptable patient exam (including SurView)
  – Raw data and noise saved, used as later reference

• Siemens: Quality Reference Effective mAs
  – Enter the effective mAs site uses in standard (approx. 80 kg) patient
  – Noise target varied on basis of patient size (empirical algorithm)
  – Topogram used to predict mA curve, on-line feedback fine tunes it

• Toshiba: Std. Deviation
  – Referenced to std. deviation of pixel values in an attenuation-equivalent water phantom, which is created from Scanogram

• All allow reference value to be stored with protocols
Thorax phantoms
Lateral dimension of 30, 35, and 40 cm
Empirically, matched noise is

- Not well-accepted clinically
- Not achievable over range of patient sizes
  - Presented constant noise images to radiologists
  - Pediatric to obese patients
  - Pediatric images were found unacceptable, even though they contained the same level of image noise
Equal noise is not acceptable because ...

- Children don’t have the fat planes between tissues and organs that adults do (fat planes enhance contrast and tissue differentiation)
- Details of interest are smaller in children, so greater CNR required
- Radiologists are accustomed to “reading through the noise” on large patients
- Radiologists require higher image quality in children to ensure high diagnostic confidence
Clinical Impact

• AEC systems that prescribe a fixed noise level systematically
  – increase dose more than clinically required for obese patients (potentially causing tube heating problems or longer scan times)
  – increase noise more than is clinically acceptable for pediatric patients (potentially yielding non-diagnostic exams)
Recommendations

• Use of a noise target technique chart
• Use of min and max mA values to prevent excessive decrease or increase of tube current
### Noise Index Technique Chart for body CT exams w/ 5 mm image thickness

<table>
<thead>
<tr>
<th>Lateral Patient Width (cm)</th>
<th>Noise Index (at 0.5 s)</th>
<th>Minimum mA</th>
<th>Maximum mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.1 – 30</td>
<td>9</td>
<td>150</td>
<td>280</td>
</tr>
<tr>
<td>30.1 – 40</td>
<td>11.5</td>
<td>220</td>
<td>500</td>
</tr>
<tr>
<td>40.1 – 45</td>
<td>14.5</td>
<td>400</td>
<td>720</td>
</tr>
<tr>
<td>45.1 – 50+</td>
<td>17 (0.7 s)</td>
<td>450</td>
<td>770</td>
</tr>
</tbody>
</table>
Beyond right-sizing the scanner output

• Children generally benefit from
  – High pitch (short scans)
  – Shortest rotation times (stop motion)
  – Lower tube potentials (increases contrast/decreases dose)
  – Thin detector collimations (need higher resolution)

• Obese patients generally benefit from
  – Low pitch (allows adequate dose)
  – Longer rotation times (allows higher mAs)
  – Higher tube potentials (to penetrate thicker body parts)
  – Thicker detector collimations (avoid electronic noise/artifacts)
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Non-uniform “wavy” streaks due to detector-level averaging of very low signal levels (“adaptive filtering”)
Thank you

Mayo CT Clinic Innovation Center and Dept. of Radiology
D. Hough, J.G. Fletcher, J. Kofler, L. Yu, S. Leng, M. Bruesewitz, T. Vrieve

http://mayoresearch.mayo.edu/CTCIC