Dosimetry and Common Pitfalls in the ACR CT Accreditation Program

Doug Pfeiffer, MS, DABR
Boulder Community Hospital
Co-Chair of ACR CTAP Physics Subcommittee

Outline
- Dosimetry
- Pitfalls

Dosimetry
- Clinical Adult Head
- Clinical Adult Abdomen
- Clinical Pediatric Abdomen (40 lb, 20 kg)
  - Must measure dose in axial mode

Axial Conversion
- Table 1
  - FDA phantoms
    - 16 cm head
    - 32 cm body
    - Non-chamber holes must be filled
    - For Pediatric Abdomen, must use head phantom on table

Axial Conversion
- Note actual z-axis (detector) collimation (T) and number of data channels (N) used
- Do not confuse z-axis collimation with nominal slice thickness!
- May not be able to achieve the same detector configuration in axial as used in helical

Particularly Pesky Scanner?
- Determine NT of detector configuration underlying the clinical helical protocol
- Select axial detector configuration most closely matching the helical NT
- Use this axial detector configuration in all subsequent calculations
- Adjust table speed in calculation to keep pitch the same

Call or e-mail the ACR
- Might be able to answer question directly
- Might e-mail the physics subcommittee
Axial Conversion

- Example: Siemens Sensation 16
  - \( N = 16, T = 1.5 \text{ mm} \Rightarrow NT = 24 \text{ mm} \)
  - Pitch = 1.2
  - Reconstructed scan width = 5 mm
  - Cannot get axial images \( N = 16 \)

So...
- Use \( T = 1.5 \text{ mm}, N = 12 \Rightarrow NT = 18 \text{ mm} \)
- Table speed = 21.6 mm in calculation

Pitch

- Must use IEC definition
  - \( \text{Pitch} = \frac{1}{N \times T} \)
  - \( I = \) table increment/speed
  - \( N = \) number of data channels used
  - \( T = \) z-axis collimation

Why?
- Still used improperly
- Confusion of relationship between \( NT, I \) and recon. scan width and increment

Dosimetry Calculations

- CTDI at central axis and periphery
  \[
  \text{CTDI}_{\text{att}} = f \times C \times E \times L / (N \times T)
  \]
  where
  - \( f = \frac{0.87 \text{ rad/R}}{} \)
  - \( C = \) electrometer/chamber correction factor
  - \( E = \) measured exposure
  - \( L = \) active chamber length
  - \( N = \) number of data channels
  - \( T = \) z-axis collimation

- CTDI\(_w\) = weighted axis and periphery
  \[
  \text{CTDI}_{\text{w}} = \frac{1}{3} \text{CTDI}_{\text{att}} + \frac{2}{3} \text{CTDI}_{\text{periph}}
  \]

- CTDI\(_{vol}\) = CTDI\(_w\)/pitch

<table>
<thead>
<tr>
<th></th>
<th>Head</th>
<th>Ped Abd</th>
<th>Adult Abd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>75</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Maximum (Pass/Fail)</td>
<td>80</td>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

Head Doses

- NOTE: Increased head reference dose does not mean that you SHOULD increase dose
- New values based on experience through CTAP
- A number of scanners could not achieve acceptable image quality at original value
- MANY SCANNERS COULD
- If images were acceptable at 60 mGy limit, leave it

Dosimetry Calculations

- CTDI\(_{vol}\) = CTDI\(_w\) * \( N \times T / I \)  (axial)
  \[
  = \frac{\text{CTDI}_{\text{w}}}{\text{pitch}}
  \]

<table>
<thead>
<tr>
<th>CTDI(_w) (Pass/Fail)</th>
<th>N</th>
<th>T</th>
<th>Pitch</th>
<th>CTDI(_{vol})</th>
</tr>
</thead>
<tbody>
<tr>
<td>58 Pass</td>
<td>4</td>
<td>5</td>
<td>20</td>
<td>--</td>
</tr>
<tr>
<td>58 Pass</td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>116 FAIL</td>
</tr>
<tr>
<td>24 Pass</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>24 Pass</td>
</tr>
<tr>
<td>27 Pass</td>
<td>--</td>
<td>--</td>
<td>0.75</td>
<td>36 FAIL</td>
</tr>
<tr>
<td>38 FAIL</td>
<td>--</td>
<td>--</td>
<td>1.5</td>
<td>25 Pass</td>
</tr>
</tbody>
</table>
Dosimetry Calculations

- DLP (mGy-cm) = CTDIvol (mGy) * total scan length (cm)
  - For ACR, assume total scan length = 17.5 cm for head
  - = 25.0 cm for adult abd.
  - = 15.0 cm for ped. Abd.

- Effective Dose (E) = k (mSv/mGy-cm) * DLP (mGy-cm)
  - Where k = 0.0021 for head
  - = 0.015 for adult abd.
  - = 0.020 for ped. abd.

- Must use appropriate spreadsheet

New Conversion Factors

- AAPM Report 96
- Monte Carlo modelling
- More accurate dose calculation

Values
- Head: k=0.0021
- Adult Abd.: k=0.015
- Ped. Abd.: k=0.020

New Conversion Factors

- Download new Phantom Dose Calculator Spreadsheets
  - Modify your own

Displayed CTDIvol = 84.0 mGy

Head Dosimetry

Adult Abdomen Dosimetry
Displayed CTDIvol = 16.9 mGy

**Pediatric Abdomen Dosimetry**

**Common Pitfalls**
- Paperwork
- Phantom
- Dose

**mA Modulation?**
- More common on modern scanners
- Do not use for Table 1, Phantom or Dose
- Determine typical mA value for your site
  - Level of umbilicus good reference
  - "Typical" patient
  - Use this value for Table 1, Phantom and Dose

**Table 1**

<table>
<thead>
<tr>
<th>Name</th>
<th>Right Side</th>
<th>Left Side</th>
<th>Right Front</th>
<th>Left Front</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>0.9</td>
<td>1.1</td>
<td>0.8</td>
<td>1.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Test 2</td>
<td>1.0</td>
<td>1.2</td>
<td>0.9</td>
<td>1.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Test 3</td>
<td>0.8</td>
<td>0.9</td>
<td>0.7</td>
<td>0.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Test 4</td>
<td>1.1</td>
<td>1.3</td>
<td>1.0</td>
<td>1.2</td>
<td>4.6</td>
</tr>
</tbody>
</table>

- Ensure that you have this
- Ensure that the data matches what they do clinically
- Verify that default protocol matches
- Evaluate to ensure that all entries are appropriate

**Alignment Accuracy**
- "Use your site’s high resolution chest technique to acquire a single axial scan at the landmark location”
  - 0.625 mm?
    - Difficult to position
    - Must see 4 beads, 1 line centered
    - ONLY for < 1 mm
  - Bad information in Table 1?
    - 3 mm
Alignment Accuracy

- MUST use slice thickness less than 2 mm
  - Except for the Siemens scanner that can't go less than 2.4 mm in axial mode!

CT Number Accuracy

- "using the technique factors listed for the Adult Abdomen technique"
  - 140 kVp?
  - Field of view?

CT Number Accuracy

- Use **SCAN** FOV appropriate for the phantom size
  - Display FOV must still be 21 cm
- Use 120 kVp (or 130 kVp if 120 unavailable)
- Must provide water CT # for **ALL** kVp settings

Slice Thickness

- New scanners may not allow larger slice thickness
  - Leave "~7 mm" box blank

Low Contrast

- Use **clinical** scan protocols
  - Must use correct mAs – match Table 1
  - If helical, must be helical
  - Must use correct pitch – match Table 1
  - Must use WW=100, WL=100

- Most scanners give some indication of helical scanning (pitch, eff. mAs, etc.)
- May not appear if PACS used – best to comment
Spatial Resolution

- Must use clinical protocols
  - Slice thickness
  - Helical
  - Reconstruction algorithm
- Must use correct window width/level
- Must use 21 cm DFOV

Dosimetry

- Ignore paper forms if provided with package
- Must use Excel spreadsheets
- Must use correct Excel spreadsheets
- Ensure correct N, T, I entered
  - May not match Table 1 if axial-helical conversion not direct
- Verify that calculated values make sense!

Physics Input

- Doses
  - New ACR limits (head higher, abd lower)
  - Appropriate for scanner
  - Dose modulation
  - Pediatric
  - Auto mA
    - Proper setting
    - Reference mA on Siemens
    - "Noise Index" on GE

Reconstruction algorithms

- High Res Chest
  - Very sharp algorithm
  - B71S (or higher) for Siemens
  - BONE for GE
- Slice thickness
  - Be aware of standard of practice
  - 10 mm head?
- High Res Chest from helical lung
- Image Gently
  - Pediatric doses scaled appropriately
Conclusions

- ACR is responding to concerns, albeit at a pace slower than some might like.
- Most mistakes, and failures, can be avoided by carefully following the directions and thinking about each step.
- Be actively involved in your site.
  - No "phantom physicist".
  - Provide support, not just testing.

For More Information

- Highly recommend:
  The phantom portion of the American College of Radiology (ACR) Computed Tomography (CT) accreditation program: Practical tips, artifact examples, and pitfalls to avoid.

The Maximum Permissible CTDIvol for Pediatric Abdomen is

1. 15 mGy
2. 20 mGy – Ped. Abd. ref. dose
3. 25 mGy
4. 30 mGy
5. 35 mGy

When scanning the phantom on a unit with automatic mA adjustment,

1. the mA specified in the ACR instructions should be used
2. the automatic mA feature should be used
3. the mA for the protocol should be used
4. the mA for average patients should be used
5. maximum mA for the protocol should be used

When scanning the phantom on a unit with automatic mA adjustment,

1. the mA specified in the ACR instructions should be used
   • the automatic mA feature should be used
   • the mA for the protocol should be used
   • **the mA for average patients should be used**
   • maximum mA for the protocol should be used

Updated Site Scanning Instructions, American College of Radiology CT Accreditation Program. Dina Hernandez, Program Specialist CT/MR Accreditation, American College of Radiology, private communication.