Radiation Doses from the ACR CT Accreditation Program: New Diagnostic Reference Values and Pass/Fail Limits

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Reference Doses

- Have been shown to lower average dose in other modalities and/or other countries
- Represent the upper third or quartile of doses sampled from actual practice data
- *Do not represent ideal or suggested doses*
- Identify when dose is unusually high


ACR CT Reference Doses

- Adult Head 60 mGy*
- Adult Abdomen 35 mGy*
- Pediatric (5 yr old) Abdomen 25 mGy

Currently no pass/fail dose criteria

- Justification or corrective action requested
- New CTDI data and images
- Low contrast resolution images
- Statement that clinical image quality is acceptable

*From European Commission EUR 16262 (2000)
European Guidelines on Quality Criteria for Computed Tomography

Phantom size affects CT DI values

Same kVp, collimation, pitch

<table>
<thead>
<tr>
<th>Phantom Size</th>
<th>200 mAs</th>
<th>Head (16 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body (32 cm)</td>
<td>110 mAs</td>
<td></td>
</tr>
<tr>
<td>Head (16 cm)</td>
<td>16.6 mAs</td>
<td></td>
</tr>
</tbody>
</table>

CTDIw = 16.6
• Use of smaller phantom and lower reference value implies that a reduction in tube output by a factor of to 3 - 4 is expected for a 5 y.o. abdomen exam
• CTDIvol values displayed on the scanner console use large CTDI phantom
  – Need to address with appropriate standards, professional and manufacturer organizations, as well as clearly educate users

Materials & Methods

Site Dose Measurements

• CTDIw (mGy) for
  – Routine head (cerebrum/brain)
  – Adult abdomen
  – Pediatric abdomen (5 y.o)
• CTDI phantom images filmed to verify correct technique

Excel® “Dose Calculator” spreadsheet

<table>
<thead>
<tr>
<th>Dose Calculator spreadsheet available for exposure or air kerma meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Body CTDI at isocenter in phantom (mGy)</td>
</tr>
<tr>
<td>12 o’clock position</td>
</tr>
<tr>
<td>Measurement 1 (mR)</td>
</tr>
<tr>
<td>401</td>
</tr>
<tr>
<td>Measurement 2 (mR)</td>
</tr>
<tr>
<td>422</td>
</tr>
<tr>
<td>Measurement 3 (mR)</td>
</tr>
<tr>
<td>401</td>
</tr>
<tr>
<td>Average of above 3 measurements (mR)</td>
</tr>
<tr>
<td>458.0</td>
</tr>
<tr>
<td>Body CTDI at 12 o’clock position in phantom (mGy)</td>
</tr>
<tr>
<td>21.0</td>
</tr>
<tr>
<td>CTDIw (mGy)</td>
</tr>
<tr>
<td>19.0</td>
</tr>
</tbody>
</table>

CTDIw = 2/3 CTDI_{100}(edge) + 1/3 CTDI_{100}(center)
Clinical exam dose estimates using measured CTDIw and site's Adult Abdomen Protocol from Table 1:

\[
\text{CTDIvol (mGy)} = \text{CTDIw} \times N \times T / I^2 \\
\text{DLP (mGy-cm)} = \text{CTDIvol} \times 25 \\
\text{Eff Dose (mSv)} = \text{DLP} \times 0.015
\]

Volume CTDI = CTDIw / pitch

Reviewer Validation

- Adult Head
  - 16 cm CTDI phantom, in head holder
- Pediatric abdomen (5 y.o.)
  - 16 cm CTDI phantom, on table
- Adult Body
  - 32 cm CTDI phantom, on table
- Axial scan mode
- Correct detector configuration
- Invalid data omitted from analysis

Data Analysis

- Average, standard deviation, and histogram determined
  - By exam (head, abdomen, pediatric abdomen)
  - By CTDIw and CTDIvol
- Statistical significance of changes in average doses by year tested using a 2-tailed t-test
- Percent of scanners above references dose determined
  - Current reference dose using CTDIw and CTDIvol
  - Proposed reference dose using CTDIvol

Results I

Mean ± standard deviation

Shown for CTDIvol only
Conclusions I

- Dose for three high-use exams have decreased significantly in the U.S. since 2002
  - Adult head
  - Adult abdomen
  - Pediatric abdomen
- Sites are “dialing down” the dose for kids
  - About a factor of 3
- ACR CT Accreditation program has developed a valuable database to monitor dose trends and to establish new reference doses
- ACR will switch to CTDIvol to include the effect of pitch

Results II

- Percent above references dose
- Establishing new reference doses
  - Maintained 5 mGy “step size”
- Mandatory dose limits

[Graphs showing dose trends for Pediatric Abdomen and Adult Abdomen from 2002 to 2004]
Adult Head

- 75%tile difficult to determine because initial reference values altered the practice distribution
- Numerous sites felt the 60 mGy was not clinically acceptable
- Multiple reports of sites increasing head dose after accreditation process completed
Data courtesy of Stanley Stern, Ph.D., U.S. FDA 2001
ACR vs. NEXT data (Head)

- NEXT 1990: 45.9 mGy ± 18.1 (n=249)
  - Solid state detectors become standard, spiral CT and higher power tubes introduced, slice width begins to decrease
- NEXT 2000: 50.3 mGy ± 19.4 (n = 203)
  - MDCT introduced in 1999, SDCT techniques used on MDCT, slice width continues to decrease
- ACR 2002: 66.8 mGy ± 23.2 (n = 127)
- ACR 2003: 58.1 mGy ± 17.4 (n = 321)
- ACR 2004: 55.5 mGy ± 15.5 (n = 214)

New UK Diagnostic Reference Levels

<table>
<thead>
<tr>
<th></th>
<th>SSCT</th>
<th>MSCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>Posterior Fossa</td>
<td>55</td>
<td>65</td>
</tr>
</tbody>
</table>


New ACR CT Reference Doses

- Adult Head       60 → 75 mGy
- Adult Abdomen    35 → 25 mGy
- Pediatric (5 yr old) Abdomen 25 → 20 mGy
Conclusions II

- Have sufficient data for new U.S. reference doses
- Based on CTDIvol to include the effect of pitch
- **Reference doses** (site given educational information)
  - Adult Head \( \rightarrow \) 75 mGy
  - Adult Abdomen \( \rightarrow \) 25 mGy
  - Pediatric (5 yr old) Abdomen \( \rightarrow \) 20 mGy
- **Maximum allowable doses** (site fails if these are exceeded)
  - Adult Head \( \rightarrow \) 80 mGy
  - Adult Abdomen \( \rightarrow \) 30 mGy
  - Pediatric (5 yr old) Abdomen \( \rightarrow \) 25 mGy
- Effective January 1, 2008

Additional Program Refinements

- Simplified Film Page 1
  - Elimination of need to convert spiral into axial
  - CT number of non-water rods only at 120 kVp
  - Fewer slice thickness scans
- New results database
- WIP
  - New performance limits
  - Accommodation of non-traditional CTDIvol measurements
  - Quality control manual
  - Electronic submissions

Thank you