Dose Alerts, Dose Notifications, and Diagnostic Reference Levels: How are they different?

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DC DISCLOSURES

Paid Speaker: MTMI, Inc.

Off Label Usage
  None
### CHM DISCLOSURES

#### Research Support:

<table>
<thead>
<tr>
<th>NIH</th>
<th>Other</th>
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<td>EB 007986</td>
<td>Society of Gastrointestinal Radiologists</td>
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<td>EB 004898</td>
<td>Mayo Novel Methodology Development Award</td>
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#### Off Label Usage

None
DC and CHM DISCLOSURES

Other
ACR CT Accreditation Program
   Past Chairs and/or Members of Physics Subcommittee
What is the “right” dose?

- The one that makes pretty pictures
- The one that the vendor specifies
- The one that you used previously
- The one presented at meetings
- The one that keeps the radiologists happy (i.e., they don’t complain)
- The lowest one you can still read
- The one “proven” to provide the required diagnostic accuracy
Diagnostic Reference Levels

• First mentioned by the International Commission on Radiological Protection (ICRP) in 1990
  – (ICRP 60)

• Recommended in greater detail in 1996
  – (ICRP 73)
Diagnostic Reference Levels

- DRLs are a form of investigation level used as a simple test to identify situations where patient dose is unusually high.
- Employ an easily measured and standardized quantity (not effective dose).
- If consistently exceeded, a local review of procedures and equipment should be performed.
- If possible, dose reduction measures should be taken.
Diagnostic Reference Levels

- Diagnostic reference levels are supplements to professional judgment and do not provide a dividing line between good and bad medicine.
- It is inappropriate to use them for regulatory or commercial purposes.
- Apply to medical exposures, not to occupational and public exposures.
- The values should be selected by professional medical bodies and reviewed at appropriate intervals.
In practice, it is simpler to choose an initial Reference Level Value as a percentile point on the observed distribution of doses in patient exams.
Reference Level Concept Endorsed by

- European Commission
- U.K. Health Protection Agency
- International Atomic Energy Agency
- National Council on Radiation Protection
- American Association of Physicists in Medicine
- American College of Radiology
U.K. Experience

• Perform regular national dose surveys
  – National Radiation Protection Board (NRPB)
• Demonstrated decreases in typical radiographic doses
  – 30% between 1984 and 1995
  – 50% between 1985 and 2000
• Reflect equipment improvements and the trend over time to reduce dose
• Data points above 75th %tile to be investigated
• Resulting adjustments narrow the dose distribution and lower the mean dose
• DRLs must
  – be defined in terms of an easily and reproducibly measured dose metric
  – use technique parameters that reflect those used in site’s routine clinical practice for average patient size
• Some surveys determine typical technique parameters and model dose metric of interest
  – Increases uncertainty due to equipment variations
• Radiographic: Entrance Skin Exposure
• Fluoroscopic: Dose Area Product
• CT: CTDIw, CTDIvol, and DLP
## DRLs from Other Countries

**Adult Diagnostic Reference Levels for CTDI<sub>w</sub> (mGy) and DLP (mGy·cm)**

<table>
<thead>
<tr>
<th></th>
<th>Head</th>
<th>Abdomen</th>
<th>Pelvis</th>
<th>Abd &amp; Pelvis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CTDI&lt;sub&gt;w&lt;/sub&gt;</td>
<td>DLP</td>
<td>CTDI&lt;sub&gt;w&lt;/sub&gt;</td>
<td>DLP</td>
</tr>
<tr>
<td>EC 1999</td>
<td>60</td>
<td>1050</td>
<td>35</td>
<td>900</td>
</tr>
<tr>
<td>ACR 2002</td>
<td>60</td>
<td>-</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>UK 2003</td>
<td>-</td>
<td>930</td>
<td>20</td>
<td>470</td>
</tr>
<tr>
<td>Germany 2003</td>
<td>60</td>
<td>1050</td>
<td>25</td>
<td>770</td>
</tr>
<tr>
<td>Switzerland 2004</td>
<td>60</td>
<td>800</td>
<td>20</td>
<td>710</td>
</tr>
<tr>
<td>Taiwan 2007</td>
<td>72</td>
<td>850</td>
<td>31</td>
<td>680</td>
</tr>
</tbody>
</table>

EC: European Commission  
ACR: American College of Radiology  
UK: United Kingdom
## DRLs from Other Countries

<table>
<thead>
<tr>
<th></th>
<th>Head</th>
<th>Abdomen</th>
<th>Pelvis</th>
<th>Abd &amp; Pelvis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CTDI\textsubscript{vol}</td>
<td>DLP</td>
<td>CTDI\textsubscript{vol}</td>
<td>DLP</td>
</tr>
<tr>
<td>Sweden 2002</td>
<td>75</td>
<td>1200</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>UK 2003</td>
<td>65-100</td>
<td>930</td>
<td>14</td>
<td>470</td>
</tr>
<tr>
<td>Netherlands 2008</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EC 2004</td>
<td>60</td>
<td>-</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>ACR 2008</td>
<td>75</td>
<td>-</td>
<td>25</td>
<td>-</td>
</tr>
</tbody>
</table>

EC: European Commission  
ACR: American College of Radiology  
UK: United Kingdom
U.S. ACR CT Accreditation Data

• Program initiated in 2002
• CTDIw measurements made for
  – Routine adult head (16 cm)
  – Pediatric abdomen (typical 5 year old, 16 cm)
  – Routine adult abdomen (32 cm)
• CTDIvol calculated using typical scan parameters
• Manual review of CTDI images and reported data performed to ensure integrity of database
  (i.e. exclude suspicious data points)
• ACR CTDIw Reference Doses
  – Adult Head 60 mGy*
  – Adult Abdomen 35 mGy*
  – Pediatric (5 yr old) Abdomen 25 mGy

• Originally no pass/fail dose criteria

*European Commission EUR 16262 (2000)
European Guidelines on Quality Criteria for Computed Tomography
Phantom size affects CTDI values

Same kVp, beam width, pitch

<table>
<thead>
<tr>
<th>Size</th>
<th>mAs</th>
<th>CTDIw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body (32 cm)</td>
<td>280</td>
<td>16.6</td>
</tr>
<tr>
<td>Head (16 cm)</td>
<td>116</td>
<td>16.6</td>
</tr>
</tbody>
</table>

\[
\text{CTDIw} = \frac{280}{2.4} = 116 \text{ mAs}
\]

CTDIw = 16.6
Phantom size affects CTDI values

- 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
- Body CTDIvol values displayed on the scanner console are supposed to use large CTDI phantom*
  - Siemens and Philips – large (32 cm)
  - GE, Toshiba and Hitachi – small (16 cm)
  - Standards, professional and manufacturer organizations are working toward harmonization on this important issue

*IEC 60601-2-44 Ed. 3
% > 2002 Reference (CTDlw)

- **Head** [60mGy]
- **Abdomen** [35mGy]
- **Pediatric Abdomen** [25mGy]
Adult Head

CTDvol (mGy)

<table>
<thead>
<tr>
<th>Year</th>
<th>75%tile</th>
<th>90%tile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>76.8</td>
<td>99.0</td>
</tr>
<tr>
<td>2003</td>
<td>63.9</td>
<td>82.2</td>
</tr>
<tr>
<td>2004</td>
<td>60.0</td>
<td>74.0</td>
</tr>
<tr>
<td>2002-2004</td>
<td>64.3</td>
<td>81.3</td>
</tr>
</tbody>
</table>

(n=117) (n=305) (n=208) (n=630)
AAPM 2011 Summit on CT Dose

Pediatric Abdomen

<table>
<thead>
<tr>
<th>Year</th>
<th>CTDIvol (mGy)</th>
<th>75%tile</th>
<th>90%tile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>20.6</td>
<td>20.5</td>
<td>26.6</td>
</tr>
<tr>
<td>2003</td>
<td>20.5</td>
<td>18.4</td>
<td>25.6</td>
</tr>
<tr>
<td>2004</td>
<td>23.4</td>
<td>20.0</td>
<td>24.9</td>
</tr>
<tr>
<td>2002-2004</td>
<td>2002-2004</td>
<td>(n=91)</td>
<td>(n=224)</td>
</tr>
</tbody>
</table>

In Press, AJR
**ACR CT Accreditation Program**

- Established U.S. CT diagnostic reference levels
- Based on CTDIvol to include the effect of pitch
- **Reference doses** (site given educational information)
  - Adult Head: 60 → 75 mGy
  - Adult Abdomen: 35 → 25 mGy
  - Pediatric (5 yr old) Abdomen: 25 → 20 mGy
- **Maximum allowable doses** (site fails if exceeded)
  - Adult Head: 80 mGy
  - Adult Abdomen: 30 mGy
  - Pediatric (5 yr old) Abdomen: 25 mGy
**DRLs for Other Exams**

- Many more CT exam types exist
- To extend benefits of DRL concept, dose surveys required for broader range of exams
- Data sources
  - European community
  - ACR CTDI registry – CTDIvol / DLP from DICOM header
  - Multi-center studies (e.g. Protection I coronary CTA)
  - Individual sites/investigators
**DRLs for Other Exams**

- The results of these surveys may extend the value of DRLs to the majority of CT applications, enabling individual CT users and the community at large to answer the question:

  “*What CT doses are typical and what doses are too high?*”
DRLs vs Dose Notifications and Alerts

- Need tools **at the point of care** that inform users if there is a potential prescription error [FDA]
  - For a specific diagnostic task (e.g. routine head)
  - “… inform users when scan settings would likely yield values of CTDIvol that would exceed pre-assigned values”
- NEMA XR 25 CT Dose-Check Standard
  - [http://www.nema.org/standards/xr25.cfm](http://www.nema.org/standards/xr25.cfm)
- Notification value – for a single scan series
- Alert value – cumulative over entire exam
  - at a given table position
AAPM 2011 Summit on CT Dose - New Feature – CT Dose Check

**Dose Alert**

A dose alert value will be exceeded!

Proceeding with this exam will exceed the dose alert level that has been set.

<table>
<thead>
<tr>
<th>Predicted Dose</th>
<th>Alert Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>263.7 mGy</td>
<td>1000.0 mGy</td>
</tr>
<tr>
<td>664.8 mGy.cm</td>
<td>6500.0 mGy.cm</td>
</tr>
</tbody>
</table>

- **Cumulative CTDIvol**
- **Patient total DLP**

**Password**

Please input a password and click the "Confirm" button to scan.

**Dose Alert - Alert value will be exceeded!**

The scan has a CTDIvol of 1255.6 mGy. This exceeds the Alert Value of 1000 mGy. This may result in an excessive level of radiation exposure.

- Enter user name:
- Enter diagnostic reason:
- Enter password:

- Confirm and proceed
- Go back and adjust scanning parameters

**Dose Alert**

<table>
<thead>
<tr>
<th>Seq No</th>
<th>CTDIvol[mGy]</th>
<th>DLP[mGy.cm]</th>
<th>Notification Value[DLP][mGy.cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>88.5</td>
<td>1327.1</td>
<td>150.0</td>
</tr>
</tbody>
</table>

Sum DLP[mGy.cm]: 1769.4
Alert Value[DLP][mGy.cm]: 1000.0
AAPM Recommendations

• AAPM Working Group on Standardization of CT Nomenclature and Protocols, which includes members from the FDA, ACR, and manufacturers, established a particular set of notification values

## Adult exams

<table>
<thead>
<tr>
<th>CT Scan Region</th>
<th>CTDIvol Notification Value (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Head</td>
<td>80</td>
</tr>
<tr>
<td>Adult Torso</td>
<td>50</td>
</tr>
</tbody>
</table>
Why are notification values so much higher than DRLs?

- DRL values typically represent the 75th percentile from a regional or national sample of clinically used dose indices for a standard patient size.

- Because ~1/3 of US population is obese, use of DRLs as notification values would result in notifications occurring very frequently, potentially de-sensitizing users and diminishing the potential value of notification values in avoiding erroneously high exposures.
AAPM notification values > DRLs

- May allow higher-than-optimal dose settings in some cases, but because they will be triggered less frequently, the tendency for users to ignore the notifications might be reduced.

- Children require different notification and alert values due to their smaller size.
**Pediatric exams**

<table>
<thead>
<tr>
<th>CT Scan Region</th>
<th>CTDIvol Notification Value (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pediatric Head</strong></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><strong>Pediatric Torso</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;10 years old (16-cm phantom)(^a)</td>
<td>25</td>
</tr>
<tr>
<td>&lt;10 years old (32-cm phantom)(^b)</td>
<td>10</td>
</tr>
</tbody>
</table>

\(^a\) As of January 2011, GE, Hitachi and Toshiba scanners use the 16-cm-diameter CTDI phantom as the basis for evaluating dose indices (CTDI\(_{vol}\) and DLP) displayed and reported for pediatric body examinations.

\(^b\) As of January 2011, Siemens and Philips scanners use the 32-cm-diameter CTDI phantom as the basis for evaluating dose indices (CTDI\(_{vol}\) and DLP) displayed and reported for pediatric body examinations.
### Specialty exams

<table>
<thead>
<tr>
<th>CT Scan Region (of each individual scan in an examination)</th>
<th>CTDIvol Notification Value (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain Perfusion (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 Retrospectively gated (spiral)</td>
<td>150</td>
</tr>
<tr>
<td>Cardiac Prospectively gated (sequential)</td>
<td>50</td>
</tr>
</tbody>
</table>
AAPM notification values are starting points

• As facilities gain more experience using the NEMA “CT Dose-Check” feature, they are encouraged to work with a medical physicist to adjust the values to better suit their individual practice

• The AAPM-recommended values do not correspond to optimal or “target” settings, are not considered acceptable “upper limits” of dose, and do not represent diagnostic reference levels
Thank you