Dose Monitoring: A Tool for Improving the Quality of Care

Olav Christianson and Ehsan Samei
Duke University

Outline

• Motivation
• Tools for dose monitoring in CT
• How dose monitoring can improve your clinical operation
  – Establishing CTDI guidelines
  – Examples of utility of dose monitoring
  – Benchmarking dose levels vs national averages
• Future developments
Health effects from ionizing radiation

Motivations for dose monitoring

1. Identify radiation overdoses and prevent future occurrences
2. Tool to improve the quality of care provided to your patients
3. Benchmark your institution against national averages

Why monitor radiation dose?

http://www.nytimes.com/2010/08/01/health/01radiation.html?_r=1
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How should radiation dose be monitored?

• CTDI

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• CTDI

• SSDE
  \[
  SSDE = CTDI_{est} \cdot f(\text{size})
  \]
How should radiation dose be monitored?

- **CTDI**

- **SSDE**
  \[ SSDE = CTDI_{eff} \cdot f(size) \]

- **Effective Dose**
  \[ ED = DLP \cdot A(\text{anatomy}) \]

- **Risk Estimate**
  \[ RI = DLP \cdot q(\text{anatomy, age, gender}) \]

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Measuring the effects of radiation

<table>
<thead>
<tr>
<th>Method</th>
<th>Size</th>
<th>Organs</th>
<th>Age</th>
<th>Gender</th>
<th>Across modalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTDI</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SSDE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Effective Dose(^1)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Risk Estimate(^2)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

1. Effective dose is only defined for reference patient, however, the concept can be modified to include a size adjustment factor.
2. Dependent on the BEIR VII data and relatively large uncertainties exist when applied to individual patients.
Optical Character Recognition

• Structured dose reports
  – Not available on all scanners

• Dose reports (screen captures)

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Measuring size

1. HU number conversion
   – Pros: Direct measure of attenuation, same range as CT scan
   – Cons: Large amounts of data, heavy cpu burden

2. Localizer pixel values
   – Pros: Less data than HU method, attenuation based, very fast
   – Cons: Conversion from PV to attenuation, edge enhancement

3. Localizer thresholding
   – Pros: Small amount of data, very fast, do not need to convert PV to attenuation
   – Cons: Not attenuation based, concerns over accuracy

* Easiest to implement on a large scale
Patient size used to improve dose estimates

LAT Dim = 31.9 cm  AP Dim = 17.7 cm

Effective Diameter = (Lat x AP)^1/2 = 23.8 cm  Normalized Dose Coefficient = 1.55

Adapted from AAPM TG 204

Matching data to series descriptors

- Series 2: Abd. Pelvis
- Series 4: Chest

<table>
<thead>
<tr>
<th>Series</th>
<th>Type</th>
<th>Dose Report</th>
<th>Scan Range (mm)</th>
<th>CTID (kVp)</th>
<th>BFP (kVp)</th>
<th>Photons cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Abd</td>
<td>152.720-193.975</td>
<td>168.4</td>
<td>168.81</td>
<td>Head 50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Head</td>
<td>106.490-129.968</td>
<td>117.0</td>
<td>78.71</td>
<td>Head 50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Head</td>
<td>145.990-185.750</td>
<td>117.0</td>
<td>78.71</td>
<td>Head 50</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>EDP</td>
<td>30726</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Study Description: Abd. Pelvis
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Radiation dose monitoring committee

- Consists of radiologists, physicians, medical physicists, radiation safety officers, and technologists
- Meet monthly:
  - Discuss cases that exceed alert levels
  - Evaluate current imaging protocols
  - Evaluate the use of techniques to reduce dose
  - Compare current protocols to national averages

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Effect of patient size

![Graph showing the effect of patient size on radiation dose](image)
Data is representative of the automatic tube current modulation algorithm. Can **NOT** conclude which system offers better performance.
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Renal Stone ect1

Patient flipped from normal orientation
Changes in patient orientation

- On some scanners, turns off AEC

- Common reasons patient orientation is changed
  - Patient unable to lie prone
  - Combining multiple studies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low Dose Series</th>
<th>High Dose Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acq Mode</td>
<td>Helical</td>
<td>Helical</td>
</tr>
<tr>
<td>Slice Thickness</td>
<td>5 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td>kVp</td>
<td>120 kVp</td>
<td>120 kVp</td>
</tr>
<tr>
<td>Rotation Time</td>
<td>0.8 s</td>
<td>0.8 s</td>
</tr>
<tr>
<td>Tube Current</td>
<td>700 mA</td>
<td>615 mA</td>
</tr>
<tr>
<td>Collimation</td>
<td>40 mm</td>
<td>40 mm</td>
</tr>
<tr>
<td>Pitch</td>
<td>1.375</td>
<td>1.375</td>
</tr>
<tr>
<td>Noise Index</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

Tube rotation time increased to avoid tube current limitations.
Repeat studies with different dose?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1st Study</th>
<th>2nd Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanner</td>
<td>VCT</td>
<td>VCT</td>
</tr>
<tr>
<td>Acquisition Mode</td>
<td>Helical</td>
<td>Helical</td>
</tr>
<tr>
<td>Slice Thickness</td>
<td>5 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td>kVp</td>
<td>120 kVp</td>
<td>120 kVp</td>
</tr>
<tr>
<td>Rotation Time</td>
<td>0.5 s</td>
<td>0.5 s</td>
</tr>
<tr>
<td>Collimation</td>
<td>40 mm</td>
<td>40 mm</td>
</tr>
<tr>
<td>Pitch</td>
<td>1.375</td>
<td>1.375</td>
</tr>
<tr>
<td>Noise Index</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>CTDI</td>
<td>4.4</td>
<td>6.3</td>
</tr>
</tbody>
</table>

45% increase in dose

Table Height | 178 | 112

8% difference in apparent AP scout size

Standard Chest on 750 HD

CTDI vs Effective Diameter

8% difference

CTDI<sub>vol</sub> vs scout table height

8% difference in apparent AP scout size
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Dose Index Registry

Courtesy of Laura Coombs, lcoombs@acr.org, 703-715-4383

DIR Registration Tracking

Courtesy of Laura Coombs, lcoombs@acr.org, 703-715-4383
Next report includes the Duke method of localizer thresholding to calculate SSDE.

DIR certified software partners

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Organ segmentation

Real time Monte Carlo simulation?

Other modalities

<table>
<thead>
<tr>
<th>Modality</th>
<th>Radiation dose metric</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computed Tomography</td>
<td>CTDI, SSD, ED, RI</td>
<td>Patient size, differences in technology, nomenclature</td>
</tr>
<tr>
<td>Nuclear Medicine</td>
<td>Injected activity, ED, RI</td>
<td>Patient size, pharmakinetics</td>
</tr>
<tr>
<td>Radiography</td>
<td>EI, ED, RI</td>
<td>Patient size, nomenclature</td>
</tr>
<tr>
<td>Fluoroscopy</td>
<td>DAP, peak-skin dose, ED, RI</td>
<td>Patient size, moving radiation field, not one correct fluorotime, data loss, nomenclature</td>
</tr>
<tr>
<td>Mammography</td>
<td>MGD, ED, RI</td>
<td>Patient size</td>
</tr>
</tbody>
</table>

One metric for all modalities?

Summary

- Dose monitoring enables standardization of radiation dose within an institution
  - Protocol, scanner, and patient size-specific CT dose guidelines
  - Improves consistency of image quality

- Examples of CT dose inconsistency caused by:
  - Changes in patient orientation
  - Tube current limitations
  - Magnification

- Benchmark radiation dose against national averages
Thank you!