ICRP 103 effective dose vs DLP vs SSDE: Which is a more clinically useful and sensitive tool for identifying outliers?

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Introduction

- There are several different ways and units used to measure and assess radiation dose associated with Radiology imaging
  - Exposure: Ability of X-rays to ionize air. Measured in Roentgen (R)\(^1\).
  - Absorbed dose: Amount of energy absorbed per unit mass of tissue. Measured in milligray (mGy) or rads. Does not take into account the radiosensitivity of the tissue.
    - CTD\(_{133}\): Average absorbed dose along the longitudinal axis of a series of continuous CT exposure\(^1\).
    - CTD\(_{LP}\) = \(\frac{1}{3}\)\(^{th}\) dose in the center of the patient + 2/3 dose on the skin surface.
  - Dose length product: Takes into account the scan length. CTDL\(_{LP}\) X Scan length. Measured in mGy-cm\(^{1/3}\).
  - SSDE (Size specific dose estimate): Patient dose estimate taking into consideration a correction factor based on the size of the patient.
    - SSDE = Correction factor x CTD\(_{LP}\) where correction factor is based on effective diameter= VAP*Lat i.e., anteroposterior and lateral diameter of the patient\(^2\).
  - Effective dose: Takes into account the organs exposed and their relative sensitivity to radiation. Measured in millisieverts (mSv). Derived using tissue weighting factor.
    - Effective dose = k x DLP where, k = weighting factor depending on the body region scanned (mSv/ mGy cm\(^{1/3}\)).
  - ICRP 103 effective dose is based on the weighting factor proposed by the International Commission for radiation protection publication 103 in 2009.
  - Different parameters take into account various patient/scan factors into consideration.
  - No definite clinical evidence related to the advantage of one vs other for clinical and research purposes.
  - Purpose of the study is to compare the ability of ICRP 103 effective dose (ED), dose-length product (DLP) and size-specific dose estimate (SSDE) to identify patients scanned with above-expected radiation dose.

Materials and Methods

- HIPAA compliant, IRB approved retrospective study.
- Routine CT abdomen and pelvis (CTAP)(single phase) with or without contrast from July 2012 to March 2013 performed on Sensation 64 Siemens scanner were included.
- Data was acquired using a commercial software (Exposure):
  - Scan parameters: mean mAs, kVp, scan length, effective patient diameter.
  - Radiation metrics: CTD\(_{vol}\), Effective dose, size specific dose estimate (SSDE), Dose length product (DLP), liver and bladder effective organ dose.
  - Effective patient diameter used to calculate the conversion factor for SSDE.

Scan Protocol:
- Helical scanning mode
- 10 mm collimation, 1:1 pitch
- 120 kVp
- CT scan with doses ≤ or ≥ 2 standard deviations (SD) beyond the mean DLP, ED and SSDE were identified and assessed.
- Mid slice effective diameter was also manually calculated using VAP*Latt (where AP = anteroposterior diameter and Lat-transverse diameter) for patients with SSDE ≤ or ≥ 2 standard deviations.
- Automatic tube current modulation
- Soft tissue (B30) reconstruction kernel
- 5 mm reconstructed section thickness

Results

- 1685 scans (995 females, 690 males) included.

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<thead>
<tr>
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<th>DLP (mGy-cm)</th>
<th>Effective dose</th>
<th>SSDE</th>
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<tbody>
<tr>
<td>Mean ± SD</td>
<td>734.7 ± 338.5</td>
<td>1411.6 ± 57.8</td>
<td>26.0 ± 29.3</td>
</tr>
<tr>
<td>&gt;2 SD</td>
<td>≥ 1411.6 mGy-cm</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>&lt; 2 SD</td>
<td>25.9 ± 0.5</td>
<td>0.97 ± 0.98</td>
<td>0.32 ± 0.97</td>
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- The calculated effective diameter for the subset of patients with SSDE ≥ 2 SD of mean was statistically similar to the automated values (p=0.34).
- Dose ≤ 2 standard deviations:
  - DLP (>57.8 mGy-cm): None
  - ED (>0.5 mSv): None
  - SSDE (<8 mGy): 4 (1 male, 3 females). Very small patients.

The organ specific ED for liver and urinary bladder demonstrated best correlation with effective dose.

Conclusion

SSDE identified the largest number of patients with above-average radiation dose and is a more sensitive indicator of patient positioning and attenuation in the field of view caused by scanning patients with arms in the field of view. DLP and ED are more sensitive indicators of scan length.

Clinical Implications

SSDE, DLP and ED are influenced by different scanning parameters, and should be used appropriately to study the influence of a particular parameter.

References

2. AAPM report number 204. Sex-specific dose estimates (SSDE) in Pediatric and Adult body CT examinations. (http://www.aapm.org/pubs/articles/rr204.pdf)

Causes of ≥ 2 standard deviations

• Dose ≥ 2 standard deviations:
  - DLP (>1411.6 mGy-cm): 35 (6 Male, 29 female).
  - ED (>25.9 mSv): 29 (12 male, 17 female).
  - SSDE (>1411.6 mGy): 47 (7 Male, 40 female).

• Correlation between dose parameters and organ dose

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<th>SSDE</th>
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<tr>
<td>Liver</td>
<td>0.95</td>
<td>0.99</td>
<td>0.26</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.97</td>
<td>0.98</td>
<td>0.32</td>
</tr>
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</table>

SSDE showed the least correlation (0.86, 0.86) which dropped as the SSDE increased (for ≥ 2 SD, correlation dropped to 0.26 and 0.32 for liver and bladder organ dose respectively).