Effective Dose in Paediatric Computed Tomography

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• Why do we need to know?

• What have we got available?

• Produce some results.

• Test the method.

• Initiate a survey.
Why do we need to know?

• CT is generally considered a high dose procedure.
• 40% of annual medical radiation dose from only 5% of the examinations undertaken.
• Little dosimetry data available for paediatric CT due to great size variation.
• We have the means!
Aims of the project.

To establish a method for calculating effective dose.

- Use easily measured parameters
Parameters?

- Height & weight
- Equivalent diameter
- CTDIw
- Dose Length Product report

\[ E_{diameter} = 2 \sqrt{ \frac{W(g)}{H(cm) \cdot \pi} } \]
What have we got available?

• A full set of paediatric dosimetry phantoms.

• Plenty of TLD.

• Access to several CT scanners.
Establish a method.

- **Fix areas of phantoms to be scanned.**
- Decide on some scanning parameters.
- Do CTDI measurements on scanner.
- TLD loaded into the phantoms.
- Scan areas of the phantoms repeatedly to accumulate a dose on the TLD.
Fix areas to be scanned

- Head & Neck
- Chest
- Abdomen
- Pelvis

Do not overlap areas
Establish a method.

- Fix areas of phantoms to be scanned.

- Decide on some scanning parameters.
  - Scan areas of the phantoms repeatedly to accumulate a dose on the TLD.
Establish a method.

• Fix areas of phantoms to be scanned.
• Decide on some scanning parameters.

• Do CTDI measurements on scanner.
  – Use weighted values from 16cm PMMA phantom
  – ‘Paediatric body’
Establish a method.

- Fix areas of phantoms to be scanned.
- Decide on some scanning parameters.
  - Scan areas of the phantoms repeatedly to accumulate a dose on the TLD.
- Do CTDI measurements on scanner.

- TLD loaded into the phantoms.
Phantoms & TLD

- All Organs containing a number of TLD.
- Most sections covered
- TLD 100
- Oven Annealing
- Calibration of TLD
- Neonate 135 TLD
- 15 year old 245 TLD
- 4 separate examinations
- Some repeats
Establish a method.

• Fix areas of phantoms to be scanned.
• Decide on some scanning parameters.
  – Scan areas of the phantoms repeatedly to accumulate a dose on the TLD.
• Do CTDI measurements on scanner.
• TLD loaded into the phantoms.
• Scan the area of the Phantom.
What next?

• Read TLD
• Calculate Effective Dose
• Calculate the Dose Length Product using the ‘paediatric body’ CTDIₘₚ
• Plot graphs of effective dose / DLP against equivalent diameter of the phantom
Effective Dose = DLP \times Y_o + (A_1 \times e^{-\frac{X}{t_1}})

Look up $Y_o$, $A_1$ and $t_1$ from the table

$X$ is the equivalent diameter of the child

Ref.
C-L Chapple, S Willis & J Frame
<table>
<thead>
<tr>
<th>Area</th>
<th>$Y_0$  (mSv mGy$^{-1}$ cm$^{-1}$)</th>
<th>$A_1$  (mSv mGy$^{-1}$ cm$^{-1}$)</th>
<th>$t_1$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>0.00351</td>
<td>0.877</td>
<td>14.2</td>
</tr>
<tr>
<td>Chest</td>
<td>0.00736</td>
<td>0.272</td>
<td>4.07</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0.00832</td>
<td>0.881</td>
<td>2.87</td>
</tr>
<tr>
<td>Pelvis</td>
<td>-0.0419</td>
<td>0.114</td>
<td>25.3</td>
</tr>
</tbody>
</table>
Test out the Theory

• Scan area to include parts of other areas
  - use some of the over-scanned phantom data
• Repeat some of the experiment on other scanners with different beam filtrations
• Get some protocols to calculate some doses
Calculation

• Example: 

Neonate Abdomen & Pelvis

• 120kV, 200mA, 10mm, 13 slices, Siemens Somatom Plus4

• 0.3 scan in Abdomen & 0.7 scan in Pelvis
Neonate Abdomen-Pelvis

4.23 mSv Abdomen

8.5 mSv Pelvis

Total for full scan = 12.7 mSv
Neonate Abdomen-Pelvis
Siemens Somatom +4

• Predicted Dose_{effective} = 12.7mSv

• Measured Dose_{effective} = 12.9mSv
5 year old Chest with Abdomen
Toshiba Asteion

• Predicted Dose_{effective} = 15.5mSv

• Measured Dose_{effective} = 17.0mSv
Real Patients.

- Neonate Head 3-12 mSv
- 5 yr High Resolution Chest 0.4-1.2 mSv
- Neonate Abdomen 7.2 mSv
- 10 yr Abdomen 4.2 mSv
- Neonate Chest-Abdomen 7.5 mSv
- 10 yrs Chest-Abdomen 5.1 mSv
Conclusion.

• We have established a method for calculating Paediatric effective doses for CT examinations.
• Can be used for a range of CT scanner.
• Tested this method.
• Calculated some real doses for real patients.
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