Managing Pediatric Patient’s CT Dose with the Help of SSDE

Keith J. Strauss, MSc, FAAPM, FACR
Clinical Imaging Physicist
Cincinnati Children’s Hospital
University of Cincinnati College of Medicine
INTRODUCTION

A. Image Gently Educational Materials
B. Effect of Patient Size on CTDI$_{vol}$ and patient dose
C. Clinical Dilemma
D. Interim Solution: AAPM TG204
E. Applications of SSDE
F. Managing Pediatric CT Patient Doses
A. The **ultimate goal** of the Alliance is to accelerate the change of local practice.

1. Problem?
2. Scientific observation to local practice change ~ 17 years!\(^1\)

\(^1\)Greenberg SB. Trans Clin Climatol Assoc 119:2450261, 2008

Adapted from Goske
Does Practice Need to Change?
How much do we really understand?

Which of the following provides a reasonable estimate of a child’s CT dose?

A. CTDI_{vol} (mGy)
B. DLP (mGy·cm)
C. Effective Dose (mSv)
D. Values in DICOM Structured Report
E. None of the above!
Does Practice Need to Change?
How much do we really understand?

Which of the following provides a reasonable estimate of a child’s CT dose?

A. CTDI$_{vol}$ (mGy)
B. DLP (mGy-cm)
C. Effective Dose (mSv)
D. Values in DICOM Structured Report
E. All of the above!
PATIENTS COME IN MANY SIZES

4 cm

1 HVL @ 120 KVP ~ 70 keV

Neonate

1 year

5 year

Adult

Large Adult
PEDIATRIC CONSIDERATIONS

A. Radiation Induced Cancer Lifetime Risk From 1 Sv Dose

1. Average
   a. 5% Males
   b. 6% Females

2. First Decade
   13 - 15%

3. Middle Age
   2 - 3 %

4. Children 3 – 5 times more sensitive

Adapted from Hall
PEDIATRIC CONSIDERATIONS

CLINICAL EDUCATIONAL MATERIALS

1. CTDI$_{\text{vol}}$ for Adults
   a. < 25 mGy Body
   b. < 75 mGy Head
   c. < 20 mGy Pediatric Body

2. Pediatric Patient Dose $\leq$ Adult Dose

3. **Limited** information prior to IG
### Abdominal Imaging Parameters

<table>
<thead>
<tr>
<th>PA Thickness (cm)</th>
<th>Approx Age</th>
<th>kVp</th>
<th>mA</th>
<th>Time (sec)</th>
<th>Pitch Abdomen</th>
<th>Pitch Thorax</th>
<th>Estimated mAs = BL x RF</th>
<th>mAs Reduction Factor (RF)</th>
<th>Estimated mAs = BL x RF</th>
<th>mAs Reduction Factor (RF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>newborn</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>172</td>
<td>0.43</td>
<td>172</td>
<td>0.42</td>
</tr>
<tr>
<td>12</td>
<td>1 yr</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>204</td>
<td>0.51</td>
<td>204</td>
<td>0.49</td>
</tr>
<tr>
<td>14</td>
<td>5 yr</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>236</td>
<td>0.59</td>
<td>236</td>
<td>0.57</td>
</tr>
<tr>
<td>16</td>
<td>10 yr</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>264</td>
<td>0.66</td>
<td>264</td>
<td>0.64</td>
</tr>
<tr>
<td>19</td>
<td>15 yr</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>304</td>
<td>0.76</td>
<td>304</td>
<td>0.73</td>
</tr>
<tr>
<td>22</td>
<td>small adult</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>360</td>
<td>0.90</td>
<td>360</td>
<td>0.82</td>
</tr>
<tr>
<td>25</td>
<td>med adult</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>400</td>
<td>1.0</td>
<td>400</td>
<td>0.91</td>
</tr>
<tr>
<td>31</td>
<td>large adult</td>
<td>120</td>
<td>400</td>
<td>fill in</td>
<td>fill in</td>
<td>fill in</td>
<td>508</td>
<td>1.27</td>
<td>508</td>
<td>1.16</td>
</tr>
</tbody>
</table>

**Notes:**
- PA Thickness: 9 cm to 31 cm
- Approximate Age: newborn to large adult
- kVp: 120
- mA: 400
- Time: fill in
- Pitch: fill in

*Estimated mAs = BL x RF, mAs Reduction Factor (RF)*

**Pediatric Considerations**

- CLINICAL EDUCATIONAL MATERIALS

---

**Image Gently Body**
8 FREE online modules for CT technologists

Module 1 - Enhancing Radiation Protection in Computed Tomography for Children

Robert Orth, M.D., Ph.D.
Marilyn J. Goske, M.D.
Cincinnati Children's Hospital Medical Center
Cincinnati, OH

© 2009 Image Gently and the Alliance for Radiation Safety in Pediatric Imaging

Toshiba, GE Healthcare, Philips, Siemens

Adapted from Goske
IG Parent Campaign
Rollout January, 2009

Parent brochures
Medical imaging
record card

What is an X-ray?
X-rays are invisible beams of ionizing radiation that pass through the body and are altered by different tissues to create 2-dimensional images of many organs.

What is a CT Scan?
CT scans use x-rays generated from a source that is rotated around the body to create 3-dimensional pictures of the body. CT studies can provide critical information for the care of your child, but obtaining the images results in more radiation exposure for the study than a single X-ray.

How much radiation is used in these exams?
We are all exposed to small amounts of radiation daily from soil, rocks, building materials, air, water, and cosmic radiation. This is called naturally occurring background radiation. The radiation used in X-rays and CT scans has been compared to background radiation we are exposed to daily. This comparison may be helpful in understanding relative radiation doses to the patient.

<table>
<thead>
<tr>
<th>Radiation source</th>
<th>Days background radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>1 day</td>
</tr>
<tr>
<td>Chest X-ray</td>
<td>1 day</td>
</tr>
<tr>
<td>Head CT</td>
<td>up to 8 months</td>
</tr>
<tr>
<td>Abdominal CT</td>
<td>up to 20 months</td>
</tr>
</tbody>
</table>

Adapted from Gosk
Educational Materials for Parents, Pediatricians

When it comes to children's CT scans, parents can have a lot of questions. Thankfully, there is a growing body of evidence-based research on the use of CT scans in children, which can help parents make informed decisions about their children's health.

When it comes to children’s CT scans, parents can have a lot of questions. Thankfully, there is a growing body of evidence-based research on the use of CT scans in children, which can help parents make informed decisions about their children’s health.

Kids aren't the only ones who have questions.

Keywords: Radiation Safety, ImageGently, ALARA

Introduction

In a recent report issued in 2004 (Ahlquist, D., et al. Pediatrics, 2004; 113: 1783-1789), the American Academy of Pediatrics (AAP) recommended that pediatricians and radiologists should work together to minimize radiation exposure in children. The report stated that CT scans are increasingly being used to diagnose and treat medical conditions in children. However, the use of CT scans can lead to significant radiation exposure, which can have long-term effects on children's health.

The report also noted that CT scans are often used to evaluate children who have acute injuries or who are suspected of having certain conditions. However, the report pointed out that CT scans are not always the best option for all children, and that other imaging modalities may be more appropriate for certain conditions. The report also recommended that pediatricians and radiologists work together to minimize radiation exposure in children.

The report concluded that radiation exposure in children should be minimized whenever possible, and that pediatricians and radiologists should work together to ensure that children receive the best possible care.
Interventional Radiology Rollout August, 2009

Safety checklist

Powerpoint talk

Parent pamphlet

Adapted from Goske
SPECIAL CONTRIBUTION

Administered Radiopharmaceutical Doses in Children: A Survey of 13 Pediatric Hospitals in North America

S. Ted Szeri, Ronald T. Davis, and Frederick H. Fehily
Division of Nuclear Medicine, Children’s Hospital Boston, Harvard Medical School, Boston, Massachusetts

University applied standards for administering radiopharmaceuticals to children, but these standards are not always followed. The US Nuclear Regulatory Commission recommends that children be treated as individuals, and that pediatric standards should be developed. Pediatric dose recommendations have not been well established. The Society of Pediatric Nuclear Medicine (Sonder et al., 2000) has recommended dose constraints for children. However, dose constraints are not widely used in practice.

Material and Methods

Children’s hospitals were surveyed to determine the doses administered to children. The survey was administered to 13 children’s hospitals. The survey included questions about the administration of radiopharmaceuticals, as well as the dose limits used. The survey was completed by a representative of each hospital.

Results

The results of the survey showed that the doses administered to children varied widely. The minimum and maximum doses were determined for each radiopharmaceutical. The dose limits used were also determined. The results of the survey are presented in the table below.

Table 1: Doses Administered to Children

<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>Minimum Dose</th>
<th>Maximum Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technetium-99m HMPAO</td>
<td>0.1 mCi/kg</td>
<td>1.0 mCi/kg</td>
</tr>
<tr>
<td>Iodine-131 MIBG</td>
<td>0.5 mCi/kg</td>
<td>5.0 mCi/kg</td>
</tr>
<tr>
<td>Iodine-131 Metaiodobenzylguanidine</td>
<td>0.2 mCi/kg</td>
<td>2.0 mCi/kg</td>
</tr>
</tbody>
</table>

Conclusion

The survey results show that there is a wide range of doses administered to children. The doses administered to children vary widely depending on the radiopharmaceutical used. The survey results also show that the dose limits used are not consistently applied.

Adapted from Goske
CT SCANNER DOSE INDICES

A. Measure dose to different size phantoms

1. Measure dose with identical scan parameters
   a. kVp
   b. mA
   c. Rotation time
   d. Bow Tie Filter

2. Use ‘CTDI’ phantoms 10, 16, and 32 cm
Measured $\text{CTDI}_{\text{vol}} = 47$

Measured $\text{CTDI}_{\text{vol}} = 37$

Measured $\text{CTDI}_{\text{vol}} = 18$

10 cm Diameter

16 cm Diameter

32 cm Diameter

$\text{CTDI}_{\text{vol}}$ increases 2.6 times as phantom size decreases!
Measured
$CTD_{\text{vol}} = 47$

Measured
$CTD_{\text{vol}} = 37$

Measured
$CTD_{\text{vol}} = 18$

Displayed
$CTD_{\text{vol16}} = 37$

Displayed
$CTD_{\text{vol16}} = 37$

Displayed
$CTD_{\text{vol32}} = 18$

Displayed
$CTD_{\text{vol32}} = 18$
CLINICAL DILEMMA

A. Displayed $\text{CTDI}_{\text{vol}}$ is:
   1. Independent of the patient size; assumes either 16 or 32 cm CTDI phantom.
   2. Method that estimates and compares the radiation output of two different CT scanners to same phantom.

B. Pediatric dose under estimated by a factor as large as 2.5 times!

C. Propagated by DICOM Structured Reports and CT scanner dose reports.
CLINICAL DILEMMA

D. Displayed $\text{CTDI}_{\text{vol}}$ is NOT... Patient dose!!
TG 204

E. Report does not:

1. Address head correction factors (< 10%)
2. Correct small (< 1%) doses from scanned projection images
3. Correct for variation (~5-10%) in attenuation of thorax vs abdomen
4. Correct small variation in pre and post contrast scans
5. Correct errors in measured dose due to x-ray beam width
F. Data from four independent investigators studying patient size correction factors.

1. Physical measurements on phantoms
   - A. Anthropomorphic Phantoms (McCollough Laboratory “Mc”)
   - B. Cylindrical PMMA phantoms (Toth / Strauss Collaboration “T-S”)
   - C. Monte Carlo Voxelized Phantoms
   - D. Monte Carlo Mathematical Cylinders (Boone Laboratory “Z-B”)

2. Monte Carlo computer modeling

Adapted from TG 204
32 cm 120 kV
Adapted from TG 204

\[ y = 3.7044e^{-0.0387x} \]
\[ R^2 = 0.9429 \]
Adapted from TG 204

16 cm 120 kVp

$y = 1.8748e^{-0.0387x}$

$R^2 = 0.9673$
G. What about scans performed at 80, 100, or 140 kVp?

1. 5% difference overall
2. 3% difference between 1 yr old (15 cm) & adult (32 cm)

Combined TS / ZB: 80-140 kVp from 120 kVp only

$y = 4.37809e^{-0.04331x}$
$R^2 = 0.97327$

Adapted from TG 204
H. What about scans performed in the thorax?

1. Thorax data from Huda et al.
2. 16% dif @ 12 cm
3. 7% dif @ 17 cm
4. < 3% dif > 17 cm

Adapted from Boone
I. What is an effective diameter?

1. Circle with area of patient’s cross section

2. Effective diameter can be estimated if the patient’s AP or lateral dimension is known.

Adapted from TG 204
Fitted equations calculate the effective diameter from either AP or LAT dimension of patient based on published data of actual patient sizes.

Adapted from TG 204
A. Same age patients vary dramatically in size. Abdomens of:
1. Largest 3 year olds and
2. Smallest adults are the same size.

Patient cross section size, not age, should be used.
K. What if I am doing retrospective dose analysis and I only know age of patient?

1. Corrections based on patient size are more accurate.

Adapted from TG 204

Effective Diameter as a function of age per ICRU 74
L. Determining patient size

1. Measure Lateral dimension with mechanical calipers.

2. Measure **Lateral** or AP dimension from **AP** or Lateral projection scan.

3. Measure AP or LAT dimension from axial scan view.

4. In #2 & #3 patient must be centered in gantry.
   a. **Magnification Error**
M. Determining size of CTDI phantom your CT scanner used to estimate CTDI$_{vol}$

1. Failure to identify correct phantom, 16 or 32 cm leads to a **systematic error of 100%**.

2. **No standard exists.** Choice may depend on:
   a. Selected protocol: adult or pediatric
   b. Selected scan field of view
   c. Year of manufacture
   d. Software level

3. **Make no assumptions:** contact manufacturer of your unit through its service organization.
## Correction Factors based on 32 cm CTDI Phantom

<table>
<thead>
<tr>
<th>Lat + AP Dim (cm)</th>
<th>Effective Dia (cm)</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>7.7</td>
<td>2.79</td>
</tr>
<tr>
<td>17</td>
<td>8.2</td>
<td>2.74</td>
</tr>
<tr>
<td>18</td>
<td>8.7</td>
<td>2.69</td>
</tr>
<tr>
<td>19</td>
<td>9.2</td>
<td>2.64</td>
</tr>
<tr>
<td>20</td>
<td>9.7</td>
<td>2.59</td>
</tr>
<tr>
<td>21</td>
<td>10.2</td>
<td>2.55</td>
</tr>
<tr>
<td>22</td>
<td>10.7</td>
<td>2.50</td>
</tr>
<tr>
<td>23</td>
<td>11.2</td>
<td>2.46</td>
</tr>
<tr>
<td>24</td>
<td>11.7</td>
<td>2.41</td>
</tr>
<tr>
<td>25</td>
<td>12.2</td>
<td>2.37</td>
</tr>
<tr>
<td>26</td>
<td>12.7</td>
<td>2.32</td>
</tr>
<tr>
<td>27</td>
<td>13.2</td>
<td>2.28</td>
</tr>
<tr>
<td>28</td>
<td>13.7</td>
<td>2.24</td>
</tr>
<tr>
<td>29</td>
<td>14.2</td>
<td>2.20</td>
</tr>
<tr>
<td>30</td>
<td>14.7</td>
<td>2.16</td>
</tr>
<tr>
<td>31</td>
<td>15.2</td>
<td>2.12</td>
</tr>
<tr>
<td>32</td>
<td>15.7</td>
<td>2.08</td>
</tr>
<tr>
<td>33</td>
<td>16.2</td>
<td>2.05</td>
</tr>
<tr>
<td>34</td>
<td>16.7</td>
<td>2.01</td>
</tr>
<tr>
<td>35</td>
<td>17.2</td>
<td>1.97</td>
</tr>
<tr>
<td>36</td>
<td>17.6</td>
<td>1.94</td>
</tr>
<tr>
<td>37</td>
<td>18.1</td>
<td>1.90</td>
</tr>
<tr>
<td>38</td>
<td>18.6</td>
<td>1.87</td>
</tr>
<tr>
<td>39</td>
<td>19.1</td>
<td>1.83</td>
</tr>
<tr>
<td>40</td>
<td>19.6</td>
<td>1.80</td>
</tr>
<tr>
<td>41</td>
<td>20.1</td>
<td>1.77</td>
</tr>
<tr>
<td>42</td>
<td>20.6</td>
<td>1.74</td>
</tr>
<tr>
<td>43</td>
<td>21.1</td>
<td>1.71</td>
</tr>
<tr>
<td>44</td>
<td>21.6</td>
<td>1.67</td>
</tr>
<tr>
<td>45</td>
<td>22.1</td>
<td>1.64</td>
</tr>
<tr>
<td>46</td>
<td>22.6</td>
<td>1.62</td>
</tr>
<tr>
<td>47</td>
<td>23.1</td>
<td>1.59</td>
</tr>
<tr>
<td>48</td>
<td>23.6</td>
<td>1.56</td>
</tr>
<tr>
<td>49</td>
<td>24.1</td>
<td>1.53</td>
</tr>
<tr>
<td>50</td>
<td>24.6</td>
<td>1.50</td>
</tr>
<tr>
<td>51</td>
<td>25.1</td>
<td>1.47</td>
</tr>
<tr>
<td>52</td>
<td>25.6</td>
<td>1.45</td>
</tr>
<tr>
<td>53</td>
<td>26.1</td>
<td>1.42</td>
</tr>
</tbody>
</table>

### Lateral Dim (cm) | Effective Dia (cm) | Correction Factor
---|-------------------|------------------|
8  | 9.2               | 2.65             |
9  | 9.7               | 2.60             |
10 | 10.2              | 2.55             |
11 | 10.7              | 2.50             |
12 | 11.3              | 2.45             |
13 | 11.8              | 2.40             |
14 | 12.4              | 2.35             |
15 | 13.1              | 2.29             |
16 | 13.7              | 2.24             |
17 | 14.3              | 2.19             |
18 | 15.0              | 2.13             |
19 | 15.7              | 2.08             |
20 | 16.4              | 2.03             |
21 | 17.2              | 1.97             |
22 | 17.9              | 1.92             |
23 | 18.7              | 1.86             |
24 | 19.5              | 1.81             |
25 | 20.3              | 1.76             |
26 | 21.1              | 1.70             |
27 | 22.0              | 1.65             |
28 | 22.9              | 1.60             |
29 | 23.8              | 1.55             |
30 | 24.7              | 1.50             |
31 | 25.6              | 1.45             |
32 | 26.6              | 1.40             |
33 | 27.6              | 1.35             |
34 | 28.6              | 1.30             |
35 | 29.6              | 1.25             |
36 | 30.6              | 1.20             |
37 | 31.7              | 1.16             |
38 | 32.7              | 1.11             |
39 | 33.8              | 1.07             |
40 | 34.9              | 1.03             |
41 | 36.1              | 0.98             |
42 | 37.2              | 0.94             |
43 | 38.4              | 0.90             |
44 | 39.6              | 0.87             |
45 | 40.8              | 0.83             |
46 | 42.0              | 0.83             |
47 | 43.4              | 0.76             |
48 | 43.9              | 0.74             |
49 | 44.4              | 0.73             |
50 | 44.9              | 0.71             |
51 | 45.4              | 0.70             |
52 | 45.8              | 0.69             |
53 | 46.3              | 0.68             |

Adapted from TG 204
Q. SSDE Accuracy

1. 20%

2. Product is an estimate of patient dose

3. Report dose estimates with proper number of significant digits

   a. SSDE $\geq 5$ mGy: integers only, e.g. 7 or 23 mGy

   b. SSDE $< 5$ mGy: one decimal point, e.g. 2.7 or 4.5 mGy
SAMPLE CALCULATION: PRESCAN

A. Determine size of patient
   1. AP Projection Scan: 16.8 cm

B. 16 cm CTDI phantom used by scanner to calculate CTDI$_{vol}$

C. Displayed CTDI$_{vol}$ = 9.29 mGy

D. 9.29 mGy x 1.08 = 10 mGy SSDE

Adapted from TG 204
SAMPLE CALCULATION: POST SCAN

A. Determine size of patient
   1. AP = 9.9 cm; LAT = 12.3 cm
   2. AP + LAT = 22.2 cm

B. 32 cm CTDI phantom assumed

C. Displayed CTDI$_{vol}$ = 5.4 mGy

D. 5.4 mGy x 2.5 = 13 mGy SSDE

Adapted from TG 204
SAMPLE CALCULATION: POST SCAN

A. Determine size of patient
   1. AP = 9.9 cm; LAT = 12.3 cm
   2. AP + LAT = 22.2 cm

B. 16 cm CTDI phantom assumed

C. Displayed CTDI_{vol} = 10.8 mGy

D. 10.8 mGy x 1.24 = 13 mGy

SSDE

Adapted from TG 204
The CTDI$_{vol}$ value reported on the scanner for the [32 or 16] PMMA phantom was used with correction factors obtained from AAPM Report 204. The correction factor for this patient was based on the patient’s [AP, LAT, AP + LAT, or effective dimension]. This method is thought to produce dose estimates with accuracy to within 20%. For this patient, the size corrected (SSDE) estimate for this CT scan is _____ mGy.
TG 204

T. Caution:

**SSDE** can **NOT** be substituted in place of **CTDI**$_{vol}$ when using k-factors to estimate Effective Doses from CT exam
Clinical Applications of SSDE

F. Can Effective Dose be used to estimate:
   1. An individual patient’s radiation dose?
   2. Organ doses?

   ABSOLUTELY NOT, despite the fact that one can find numerous published papers that make this error!!
Clinical Applications of SSDE

G. Effective Dose is **NOT**:  
1. A patient dose  
2. To be used for an individual  
3. Defined for children  
4. For estimating cancer risk; it assesses more than just cancer risk.

Clinical Applications of SSDE

H. Effective Dose Recommended Reading

1. ICRP 103 Executive Summary


Clinical Applications of SSDE

A. Child imaged on unit 1 on Tuesday followed by second examination on Wednesday on unit 2 (different manufacturer) in same department.

1. Unit 1: Displayed CTDI$_{\text{vol}(16)}$ = 11 mGy
2. Unit 2: Displayed CTDI$_{\text{vol}(32)}$ = 5 mGy

B. Mom & Dad were not pleased!

C. SSDE ~ 13 mGy for each of two studies!
Clinical Applications of SSDE

D. SSDE

1. Is useful as a first approximation of some organ doses
   a. Soft tissues only
   b. Organ completely in scan volume in z direction.
Clinical Applications of SSDE

D. SSDE

1. Is useful as a **first approximation** of some organ doses
   c. Radial dose profiles
d. Range dependent on patient diameter
e. Single estimated average (83)
Clinical Applications of SSDE

D. SSDE

1. Is useful as a first approximation of some organ doses
   
f. Increased error for small organs

Adapted from McCollough
Clinical Applications of SSDE

E. SSDE can be used to:

1. Estimate a patient’s radiation dose
2. Report estimated patient dose in the patient’s medical record
3. Estimate organ doses in some cases while more accurate estimates of organ dose to an individual patient are being developed.
Clinical Applications of SSDE

I. Ideally, unique scan parameters should be established for each individual patient accounting for:
   1. Patient size
   2. Type of CT examination
   3. Design of actual CT scanner

J. This can be done in academic centers with diligent effort.
Clinical Applications of SSDE

K. What are the odds this will happen for the occasional pediatric CT scan completed at a good community hospital?

SLIM & NONE!

Yet, majority of pediatric CT imaging in US DOES NOT occur in dedicated pediatric hospitals?
Clinical Applications of SSDE

L. What is a solution?

1. Calculate SSDE after scan projection image of patient is complete.
   a. Measured patient width
   b. Size of CTDI phantom used by imager
   c. CTDI\textsubscript{vol}

2. Compare calculated SSDE to reference SSDE

3. Adjust scan parameters as necessary.
M. Reference Doses in a pediatric department might be:

1. 10 cm (Newborn) \sim 0.6 \times \text{adult SSDE}
2. 11 cm (1 yr old) \sim 0.7 \times \text{adult SSDE}
3. 14 cm (5 yr old) \sim 0.8 \times \text{adult SSDE}
4. 17 cm (15 yr old) \sim 0.9 \times \text{adult SSDE}
5. 23 cm (Adult) \sim \text{adult SSDE}
Managing Pediatric CT Patient Doses

N. Should voltages < 120 kVp be used for Children?

1. **Reduced high voltage; same dose**
   a. Set appropriate reduced mAs
   b. Note displayed CTDI$_{vol \ 120}$
   c. Reduce kVp
   d. mAs up until CTDI$_{vol \ 80} = CTDI_{vol \ 120}$
   e. **Increased** Contrast at ~ same dose
Managing Pediatric CT Patient Doses

2. Reduced high voltage; reduced dose
   a. Dial up reduced mAs technique
   b. Note displayed CTDI_{vol} 120
   c. Measure increased contrast at 80 kVp compared to 120 kVp.
      i. ACR accreditation phantom
      ii. Clinical FoV / Bow tie Filter
2. Reduced high voltage; reduced dose
   d. Estimate increase in noise by comparing $\text{CTDI}_{\text{vol} \ 120}$ & $\text{CTDI}_{\text{vol} \ 80}$
   e. Contrast Up 40% / Noise Up 60%
   f. Increase mAs at 80 kVp until Noise increases only 40%
   g. $\text{CNR}_{80 \ \text{kVp}} = \text{CNR}_{120 \ \text{kVp}}$
   h. Same Image Quality; Reduced Dose
Conclusions

A. Due to variations in:
   1. Patient size,
   2. Type of CT examinations, and
   3. Design of actual CT scanners,

   Patient’s CT dose should be appropriately
   1. Estimated,
   2. Managed during the examination, and
   3. Recorded,

   regardless of patient size!

   SSDE can help with all three tasks!
Conclusions

B. Adult hospitals performing 80% of all pediatric CT Examinations **should** manage their pediatric radiation doses.

1. Use adult protocols and calculate adult SSDE.
2. SSDE of pediatric patient prior to scan <
   - a. SSDE for adult patient.
   - b. Established reference SSDE by Dept.
3. Changing kVp is more involved, but addresses:
   - a. Image quality improvement