Radiation Dose Reduction in Pediatric CT

Arastoo Vossough, MD, PhD
Associate Professor of Radiology
Disclosures:
No relevant conflicts of Interest
Objectives

• To be aware of advances in CT applications and dose reduction in pediatrics.

• To become familiar with resources available to help implementing radiation dose reduction.

• To become familiar with the various modifications that can be done to reduce neuroradiological CT examination radiation doses in pediatrics (on both older and newer generation scanners).
(Reuters) - Radiation from CT scans done in 2007 will cause 29,000 cancers and kill nearly 15,000 Americans, researchers said on Monday.

By Julie Steenhuyisen
CHICAGO | Mon Dec 14, 2009 4:30pm EST

Cancer on msnbc.com

15,000 will die from CT scans done in 1 year

Scans have higher levels of radiation than thought, researchers say

Will You Be one of the 15,000 That Are Killed By CT Scans Next Year?
This is the question being asked as 2009 drew to a close.
## The AAPM

### Professional/Education/Science Policies

<table>
<thead>
<tr>
<th>POLICY NUMBER</th>
<th>POLICY NAME</th>
<th>POLICY DATE</th>
<th>SUNSET DATE</th>
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Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be nonexistent. Predictions of hypothetical cancer incidence and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged. These predictions are harmful because they lead to sensationalistic articles in the public media that cause some patients and parents to refuse medical imaging procedures, placing them at substantial risk by not receiving the clinical benefits of the prescribed procedures.

AAPM members continually strive to improve medical imaging by lowering radiation levels and maximizing benefits of imaging procedures involving ionizing radiation.
In accordance with current knowledge of radiation health risks, the Health Physics Society recommends against quantitative estimation of health risks below an individual dose of 50 millisievert (mSv) in one year or a lifetime dose of 100 mSv above that received from natural sources. Doses from natural background radiation in the United States average about 3 mSv per year. A dose of 50 mSv will be accumulated in the first 17 years of life and 0.25 Sv in a lifetime of 80 years. Estimation of health risk associated with radiation doses that are of similar magnitude as those received from natural sources should be strictly qualitative and encompass a range of hypothetical health outcomes, including the possibility of no adverse health effects at such low levels.

There is substantial and convincing scientific evidence for health risks following high-dose exposures. However, below 50–100 mSv (which includes occupational and environmental exposures), risks of health effects are either too small to be observed or are nonexistent.
initial CT [P22]. Compared to children who received <5 mGy to the brain, those who received 50-74 mGy (mean of 60.4 mGy) had a RR of 2.82 (95% CI: 1.33, 6.03), and all those with ≥50 mGy (mean of 704.2 mGy) had a RR of 3.32 (95% CI: 1.84, 6.42). They further reported a significant increase in the RR with increasing age at exposure. However, there are concerns about the risk estimates because of lack of information about indications for the CT scans and the consequent potential for “reverse causation” (i.e. cancers may have been caused by the medical conditions prompting the CT scans rather than by the CT dose) and lack of individual dosimetry.

B206. Brain tumour incidence among 860,000 persons following paediatric CT examinations was recently reported in comparison with 10 million persons without a report of a CT examination [M9]. For brain cancers diagnosed one or more years after the initial CT examination, they reported a relative risk of 2.44 (95% CI: 2.12, 2.81; n = 210) for those who received CT examinations of the brain, and a brain cancer relative risk of 1.51 (95% CI: 1.19, 1.91; n = 73) after CT scans of other body locations. The 50% elevated risk for brain cancer after receiving CT examinations at non-brain sites suggests the potential for bias in the study. When they further examined the radiation dose response for brain cancer risk with different lag periods after brain CT examinations, they found ERR Gy⁻¹ estimates of 29 (95% CI: 23, 37), 21 (14, 29) and 15 (7, 26) for lag times of 1, 5 and 10 years, respectively. The implausibly early risk that declined with time suggests the possibility of “reverse causation”.
Threshold vs no Threshold
## Dose Report

<table>
<thead>
<tr>
<th>Series</th>
<th>Type</th>
<th>Scan Range (mm)</th>
<th>CTDI&lt;sub&gt;vol&lt;/sub&gt; (mGy)</th>
<th>DLP (mGy·cm)</th>
<th>Phantom cm</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Scout</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>2</td>
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<td>51.18</td>
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<td>Head 16</td>
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<tr>
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<td>6</td>
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<td>1116.250–553.750</td>
<td>54.39</td>
<td>1149.83</td>
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</tbody>
</table>

**Total Exam DLP:** 3536.77

### CT Dose:

CTDI<sub>vol</sub> x Z-axis length = DLP (dose length product)
Reducing CT Radiation Exposure

• Don’t scan if unnecessary
  • Trauma Head CT rules, panscan, ICU patients, multi-perfusion

• Scan only specific areas needed
  (e.g., entire vs part of spine, face, neck)
  (DLP = CTDI x length of scan)

• Don’t do multiphase studies if unnecessary

• Consider other modalities

• Paradigm shift: from highest image quality to what’s good enough for the clinical question
ALARA Principle
(i.e., Good Enough)

“Consideration for radiation protection should include the fact that imaging professionals must think about acceptable image quality as opposed to optimal quality.”

Reducing CT Dose

CTD\textsubscript{Ivol} (Head) = 77.30 mGy

CTD\textsubscript{Ivol} (Head) = 20.87 mGy
Neuro CT Scenarios

- CT, s/p trauma
- CT, check ventricle size
- CT, r/o stroke
- CT, craniofacial deformities

- Head CTA, after clipped aneurysm
- Head CTA, r/o stroke
- Neck CTA, pencil injury to posterior throat

Do they all need the same dose?
What’s Different in Pediatrics

• Scanner output vs. patient dose
  – Conversion factor from mGy to mSv is different in Peds

• Pitfalls of volume CTDI and DLP
  – CTDI is referenced to phantom (32cm vs 16cm)
  – Can underestimate dose to very small patients
  – Different manufacturers’ or different protocols’ modelling may vary
  – Size-specific dose estimates (SSDE) vs CTDI (Siebert, JA et al, JACR 2014)
ACR Accreditation for CT

CTDI$_{vol}$: Volumetric CT Dose Index

- **ADULT:**
  - CTDI$_{vol}$: 80 mGy

- **CHILDREN:**
  - Diagnostic reference level: CTDI$_{vol}$: 35 mGy (1 yo)
  - Pass/fail limit: CTDI$_{vol}$: 40 mGy
    - (for a routine 1-year-old head exam - may be different (higher or lower) for an individual patient with unique indications).
Radiology Safety - What can I do?

Whatever role you play in caring for children, you can pledge to image gently.

Different members of the imaging team and members of the community play different roles in using the image gently philosophy to ensure that radiology procedures in children are performed in the best way possible. Every care setting is unique.

We suggest you read the recommendations for your role AND browse through the other links as well to best implement the changes in your practice to child-size the protocols at your site. To the right is a wealth of information in CT, Nuclear Medicine, and Interventional Radiology.
Technical factors in Reducing CT Radiation Dose

- Tailor dose to patient size
  - Age/size based categories, automated tube current modulation, automated tube voltage modulation
- Use of radiation shields
- Use of lower kVp of 80 or 100 or 120 if possible
- Minimizing Z axis scan length
- Optimize pitch per clinical indication
- Optimize collimation per clinical indication
- Accurate patient centering in the gantry
- Iterative reconstruction techniques instead of backprojection if available
- Optimize the dose performance of detector, collimator, and beam-shaping filter
Reducing CT Radiation Dose

1. Tailor technical factors to indication and patient – even on old scanners

1. Automatic exposure control

1. Iterative reconstruction
Gantry Tilt
Optimize mAs

- Tube current (mA) = rate of x-ray production

- Decrease of tube current and exposure time (mAs) decreases dose but increases noise/quantum mottle

- Can be quite low for airway or lung parenchyma

- Can be lower for children
Optimize mAs

\[ \text{CTDI}_{\text{vol}} = 5.3 \]
# Table II: mAs Reduction Factors for the Pediatric Head

<table>
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<tr>
<th>Room #:</th>
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<table>
<thead>
<tr>
<th>Head Baseline:</th>
<th>kVp</th>
<th>mA</th>
<th>Time (sec)</th>
<th>Pitch</th>
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<table>
<thead>
<tr>
<th>PA Thickness (cm)</th>
<th>Approx Age</th>
<th>mAs Reduction Factor (RF)</th>
<th>Estimated mAs = BL x RF</th>
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<td>12</td>
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<tr>
<td>16</td>
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<tr>
<td>17</td>
<td>6 yr</td>
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<tr>
<td>19</td>
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</table>

1. Type in baseline head techniques and mAs in yellow cells
2. Spreadsheet will calculate mAs estimated for pediatric patients of varying sizes
Optimize pitch

• Pitch = distance CT table advances in 1 rotation / width of x-ray fan beam in z direction – definition in high MDCT

• Increased pitch decreases dose & likelihood of motion artifact but increases quantum mottle

• Variable based on clinical indication

• Needs to be low for temporal bone CT studies
X-ray beam on less than a full rotation
Automatic Tube Current Control

- Tube current changes during course of scan base on presets
  - Set upper limit

- Different manufacturers:
  - Translation of same dose levels is not easy
  - Same dose levels may not produce identical image quality
Automatic Tube Current Control

3 y/o

15 y/o
CT Scouts (Scanograms)

- Center the patient in the gantry
  - Helps the automated does reduction measures work more accurately
  - Reduces dose

- AP vs. AP and lateral

- Dose of scout
Iterative Reconstruction

- Use an iterative reconstruction instead of filtered back projection

- ASIR, SAFIRE, iDose\(^4\), AIDR

- Newer generation (model based): ADMIRE, Veo, IMR

- Allows acceptable quality scans at much lower doses
Iterative Reconstruction

None

Mild

Strong

CTD\textsubscript{vol} = 7
Reducing CTA Dose

K-edge of iodine

Can go lower on kVp

$\text{CTDI}_{\text{vol}} = 5$
Dual Energy CTA

80kVp

140kVp
Dual Energy CTA

- Dose neutral?
Dose Index Registry

The Dose Index Registry (DIR) is a data registry that allows facilities to compare their CT dose indices to regional and national values. Information related to dose indices for all CT exams is collected, anonymized, transmitted to the ACR, and stored in a database. Institutions are then provided with periodic feedback reports comparing their results by body part and exam type to aggregate results. Data collected from the registry will be used to establish national benchmarks for CT dose indices.

The American Board of Radiology has qualified the DIR registry as meeting the criteria for practice quality improvement (PQI), towards the purpose of fulfilling requirements in the ABR Maintenance of Certification Program.

Read more about DIR >>

Please see our Registration Process and Fee Schedule to get started with the registration process.

Note: If a PDF does not open when you click on it, right click on the PDF link and choose ‘save target as’ or ‘save link as’ to save the PDF to your computer. Click on the saved document to open.

DIR-Certified Software Partners

The software providers listed below offer products that provide data in a format acceptable to the DIR. However, these products are not required for participation.

- AWARE
- DoseMonitor
- IMALOGIX
- IMAGING3.0
- PRIMORDIAL
- Radiance
- Radimetrics
- SECTRA

DIR is IMAGING 3.0

NRDR RESOURCES
- Master-Child User Guide
- New Facility Registration
- Registration Process and Fee Structure
DIR Facilities with Pediatric Exams
Jan2013 - Jun2013
CT HEAD BRAIN WO IVCON - CTDivol Boxplot, Age group 3-6

<table>
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Facility ID=100457
Page 109
Jan2013 - Jun2013 V2
Reducing CT Radiation Dose in Pediatrics

• ALARA – good enough scans

• Technical modifications regardless of generation of scanner

• Needs some degree of personalization per each indication and/or patient

• Needs radiologist time in protocolling