2016: Advances in CT Dose Reduction Techniques in Children

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Learning Objective - To Understand

- Basic CT dose reduction “tricks” in a young population
The Five Easy Tricks in Kids

• Limit scan range to region of interest
• Limit the number of contrast phases
• Center the patient
• Tailor CT parameters
  – Increase the collimation
  – Lower kVp, mAs
• Use iterative reconstruction

#1 Limit Z-Axis Coverage (Image Creep)

- Easiest adjustment
- Use a low-dose “scout” scan to determine the minimum scan range
- ”shrink to size”
#2 Limit the Phase Creep

- Unnecessary multiphase exams add substantial excess radiation

- **KEY CONCEPT:** image during one phase
  - Arterial phase for CT angiography
  - Venous phase for other imaging

- Exception: liver masses (2 phases)

- **You don’t need non-contrast scans**

Siegel MJ, Effects of Automated kilovoltage selection technology in pediatric CT and angiography. Radiology 2013; 268:538-547
Tumors
Large and well seen in venous phase
Vascular Lesions
Scan in the arterial phase

Right arch
Coarctation
Sequestration
#3 Center the Patient

- Centering the patient in the gantry is VITAL
- Mis-centering (vertically or laterally) of only 2.2 cm from isocenter can increase CTDI$_{vol}$ by 23% and image noise by 7% due to inaccurate AEC modulation
- Errors are more likely in smaller patients

# 4 Tailor the CT parameters
Increase the collimation

- Avoid very thin slices--
  - To compensate for increase in noise, need to increase the mAs, which in turn will increase radiation exposure to soft tissues
  - Collimation 0.6 – 1 mm for routine CT (tumor, trauma, appendicitis)
  - Very thin collimation only for coronary CT

Siegel MJ, Effects of Automated kilovoltage selection technology in pediatric CT and angiography. Radiology 2013; 268:538-547
#4 Tailor the CT parameters
Lower the mAs and kVp

- mAs and kVp have greatest effect on output
- $\text{CTDI}_{\text{vol}}$ is directly proportional to mAs
- $\text{CTDI}_{\text{vol}}$ is approximately proportional to the square of the percentage change in kVp
- 50% decrease in mA = 50% dose decrease
- 80 kVp = 30% to 50% dose decrease

Siegel et al. Radiology 2004; 233:515-522
How do you select the best parameters?

- **Two options**
- **Manual technique charts (based on weight, circumference, BMI) and CT task**
  - “best guess” approach
- **Automated technology**
  - Tube current (mA) modulation
  - Tube voltage (kV) reduction
  - Iterative reconstruction

Tamm et al.  CT dose reduction: how to implement change without sacrificing diagnostic quality. Radiographics 2011; 31; 1823-1832
Automated Current (mA) Modulation

- Vendor specific
- mAs selection based on vendor specific reference parameter to meet a desired level of image quality

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Trade name</th>
<th>Image quality reference</th>
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<tbody>
<tr>
<td>General Electric</td>
<td>Smart mA</td>
<td>Noise index</td>
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<td>Philips</td>
<td>DoseRight</td>
<td>Reference image</td>
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<td>Siemens</td>
<td>CARE Dose4D</td>
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<td>Toshiba</td>
<td>SureExposure</td>
<td>Image quality level</td>
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</table>
Tube Current (mA) Modulation

- mA selected based on the topogram
- Parts with less thickness need less radiation
- Dose reductions: 26% to 65%
Ex: shoulders to pelvis
Ref value 150 mA
Automated mAs Modulation

- 4 year old. R/O lung anomaly
- **Ref mAs 110**
- **Actual mA-40 (mean)**
- **kVp-100**
- **Eff dose 0.67 mSv**

Great image quality
Automated kV Technology

- Selects the optimal kV based on the attenuation profile from the scout and diagnostic task
- One kVp selected for entire scan (not per scan)
Auto kV in Pediatric Patients

- 87 children (1 day to 19 yrs)
- CTDI\textsubscript{vol} using auto kVp + mAs compared to estimated CTDI\textsubscript{vol} using 120 kVp and auto mAs

**Results**

- kVp reduced below 120 kVp in > 95%
- with auto kVp: median CTDI\textsubscript{vol} 4.8 mGy
- without auto kVp: median CTDI\textsubscript{vol} 7.1 mGy
- Mean reduction= 2.3 mGy (27%)
  
  » CTA 60%, chest CT 27%, abdomen CT 26%

Auto kV Selection in CTA

- 56 mAs, 70 kVp, 0.47 mSv
- 50 mAs, 70 kVp, 1.8 mSv
- 50 mAs, 80 kVp, 2.2 mSv
Auto kV Selection: Abdomen CT
**Lower the kVp**

- Automated kVp best option if available
- If not, use weighted based tables

<table>
<thead>
<tr>
<th>Weight (Kg)</th>
<th>chest</th>
<th>Abdomen</th>
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<tbody>
<tr>
<td>&lt;10</td>
<td>70/80</td>
<td>80/100</td>
</tr>
<tr>
<td>10-19</td>
<td>80</td>
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<td>100</td>
<td>120</td>
</tr>
<tr>
<td>50-64</td>
<td>100</td>
<td>120</td>
</tr>
</tbody>
</table>


*Yu et al. Radiation dose reduction ion pediatric body CT using iterative reconstruction. AJR 2015; 205:1026-1037*
## Iterative Reconstruction

### Vendor Specific

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>General Electric</td>
<td>ASIR, MBIR</td>
</tr>
<tr>
<td>Philips</td>
<td>iDose</td>
</tr>
<tr>
<td>Siemens</td>
<td>IRIS, SAFIRE, ADMIRE</td>
</tr>
<tr>
<td>Toshiba</td>
<td>AIDR</td>
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</table>
Iterative Reconstruction

- Post processing algorithm to clean up image noise levels
- Scan at lower mA or higher noise index
- Then IR “cleans up” the image noise
- Dose reductions in pediatric CT—22% to 48%, varying with region scanned
Iterative Reconstruction

$\sigma = 26.8 \text{ HU}$

$\sigma = 7.8 \text{ HU}$

30% mAs reduction
High noise

IR 3X less noise
Lower dose (30%)
#5 Shield Superficial Organs

- **Thyroid** and **breast** in chest CT scans and **gonads** in pelvic CT receive high doses, although they are *not* areas of interest for the CT.
- These structures are very sensitive to radiation.
Breast Exposure: What are the options?

- Bismuth shields
- Automated mA modulation
- Automated organ based current reduction
Breast Dose Reduction

• Bismuth shields
  – 30-50% dose reduction; 40-100% noise increase

• Automated mAs reduction or automated organ based current reduction
  – 30-60% dose reduction, 10-30% noise increase
  – “win-win” scenario

AAPM Position Statement on the Use of Bismuth Shielding for the Purpose of Dose Reduction in CT scanning 2012

Geleijins Eur Radiol 2006; 16:2334
Vollmar, Kalendar Eur Radiol 2008
AAPM Position Statement on the Use of Bismuth Shielding for the Purpose of Dose Reduction in CT scanning Feb 2012

“For equivalent levels of image noise, the percent dose reduction to the anterior surface from bismuth shielding can be achieved by reducing the x-ray tube current”

Pediatric CT

- The challenge in pediatric CT is to dial down the dose and drive up imaging quality
- The answer: appropriate utilization and “patient sized” low dose CT parameters