OPTIMIZING CT IMAGING IN CHILDREN

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OPTIMIZING CT IMAGING IN CHILDREN

• Personnel
• Preparation
• Protocol
• Performance
• Postprocessing
• Interpretation and Communication

PERSONNEL

• Schedulers - knowledgeable, facilitative - access for consultation
• Child Life – preparation/distraction
• Nurses – adept at dealing with children/parents, assessing ability to cooperate, need for sedation, IV access and monitoring
• Anesthesiologists - understand level of sedation needed, prevention of atelectasis in chest CT, lung recruitment, breathhold techniques
• CT Technologists – skilled in handling/restraining children, know the equipment and appropriate protocols for age and indication, understand and use dose saving measures
• Radiologists - knowledgeable about appropriate indications, correct protocol, equipment and dose saving capabilities, skilled interpretation of pediatric diseases

PREPARATION

• Clinical information /correct study
• Protocol
• Cooperation/sedation/anesthesia
• Realistic expectations
• Child life help, distraction aids
• Oral contrast
• IV access - plan for site, type of contrast, volume, method and speed of delivery, saline chaser

PROTOCOLS

• First study versus followup
• High detail, lower detail options- resolution needed
• Standard CT vs CT angiography- spatial and contrast resolution interplay
• Contrast- IV and/or oral
• IV access- type and speed

PERFORMANCE

• Scanner/room distractors
• Efficient
• Proper positioning
• Swaddling, reassurance, comfort, parent
• Protection- lead apron, thyroid shields for nurse, anesthetist, parent ? patient,thyroid,breast shield
• Nurse/physician in scanner to monitor contrast injection
• Follow protocol of scan including parameters , contrast delivery and scan delays
• Rapid scan quality check
18 m / boy – gross patient motion

POSTPROCESSING
• Source images and various reconstructions along with protocol page sent to PACS
• Chest CT Routine reconstructions include:
  1. Axial 3-5mm soft tissue algorithm(B30)
  2. Axial 2mm lung algorithm (B60)
  3. Axial MIPS 5-8mm thick 3-5mm apart
  4. Coronal MPR- 2mm (B45)
  5. Sagittal MPR- 2mm (B45)
  6. Postprocessing interaction with data on 3D workstation with additional MIPS, MINIPS, CPR, 3D volumetric reconstructions and saved images as appropriate

INTERPRETATION AND COMMUNICATION
• View multiple windows (soft tissue, lung, bone) and planes (axial, coronal, sagittal). Interact with data on 3D workstation as needed
• Document technique, dose indices and findings
• Dictation to include description of positive and pertinent negative findings. Impression- review and give opinion/conclusion of important findings
• Documentation of any problems e.g. contrast reaction, IV infiltration and their management
• Prompt communication of results. Direct communication of critical results

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Multiple Chest CT Protocols
• Gap:CT (3mm thick) – child/patient, noncontrast
  - detail of lung parenchyma/bronchi
  - individual scan slices may require more than one breathhold
  - implantable devices: large areas not covered
  - 100kVp, 30 mAs
  - lower dose about 50-70% less than routine chest CT dose.
• Protocol: spiral chest CT – noncontrast CT (3-5mm)
  - protocol varies with age/weight, 80-100kVp, ref mAs 25, pitch 1
  - start study opposite Albers into contrast injection
  - dose “shrink”, can do lower dose or limited followup
  - CPR (for occasional) –
    - 3mm thin spiral triggered study, 4 sec delay, with rapid dynamic IV contrast
    - 80-100kVp, ref mAs 100-150
    - dose “shrink” more than routine contrast chest CT
• Gated CT: cardiac, small moving vessels (e.g. coronaries)
  - 75mm, multiple slices throughout the cardiac cycle at each level
  - 80-100kVp, ref mAs 500
  - dose 3-4X routine chest CT with current retrospective gating
• Indeterminate chest CT
  - Axial/50% overlap
  - LDL, 30kVp
  - with inspiratory, expiratory 1.2
  - Ax 20-100 I before chest surgery.
Contrast for Pediatric CT

Children have little body fat and poor natural tissue contrast
- IV contrast (2cc/Kg) - almost always desirable for body CT unless specifically contraindicated e.g. renal dysfunction (Creatinine clearance <)
- Oral contrast - usually desirable for abdominal CT except for CT angiography and some emergencies. Usually some better than none
- Occasionally need rectal contrast

Chest: Noncontrast vs Contrast

6mos SVC obstruction – hand injection PICC

15mos noncontrast
Incr. Creatinine

Abdomen- Kidneys/Liver

15mos noncontrast renal dysfunction
Good peripheral IV injector 12yoF
RT. pyelonephritis

Suboptimal contrast
IV infiltrated

Pediatric Radiology Peripheral and Central IV Access Guide Contrast Dose: CT 2-3cc/Kg

<table>
<thead>
<tr>
<th>Study</th>
<th>Purple PICC and purple Mediport power needle access – confirm tip location</th>
<th>All other PICCs, ports and central lines – 4Fr confirm tip, blood return, easy flush</th>
<th>18-20 g up to 6cc/sec</th>
<th>22 g &gt;3.2cc/sec</th>
<th>24 g &gt;3.2cc/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection Method</td>
<td>Power</td>
<td>Hand</td>
<td>Power Hand</td>
<td>Power Hand</td>
<td>Power Hand</td>
</tr>
<tr>
<td>CT head/neck</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>Suboptimal *</td>
</tr>
<tr>
<td>CT chest (alone)</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>Suboptimal *</td>
</tr>
<tr>
<td>CT abdomen/pelvis</td>
<td>Acceptable</td>
<td>Very suboptimal</td>
<td>Acceptable</td>
<td>Suboptimal</td>
<td>Very suboptimal *</td>
</tr>
<tr>
<td>CT angiocardio/ head &amp; neck</td>
<td>Acceptable</td>
<td>Unacceptable</td>
<td>Acceptable</td>
<td>Suboptimal</td>
<td>Very suboptimal *</td>
</tr>
</tbody>
</table>

3yo Wilm’s – IV1 and mets Mediport Hand Injection

3yo Wilm’s – IV1 and mets Mediport Hand Injection

12/4/09 Rt arm peripheral IV- injector
1/15/10 Mediport hand injection
IMAGING USING IONIZING RADIATION IS AN ESSENTIAL PART OF MODERN MEDICAL MANAGEMENT

- ALARA PRINCIPLE – Radiation Dose Should be As Low As Reasonably Achievable.
- www.imagegently.com

IONIZING RADIATION

- MEDICAL IMAGING IS RESPONSIBLE FOR APPROXIMATELY 40-50% OF POPULATION RADIATION EXPOSURE IN THE U.S.- 62 MILLION STUDIES/yr
- CT ACCOUNTS FOR 17% OF MEDICAL IMAGING BUT 75% OF MEDICAL RADIATION. ONE CT = ABOUT 100-150 CXR’S
- 11% OF CT SCANS ARE IN CHILDREN

IONIZING RADIATION AND CANCER

- CONCERN FOR CANCER INDUCTION BY IONIZING RADIATION
- small risk, 1 in 1,000-1 in 2,000 for 1CT(10mSv) = .05%. Lifetime cancer risk for population overall (40%)
- Children, especially infants, female>male have greater organ sensitivity to radiation (breast, thyroid, gonads)
- Increased organ dose in children because of less peripheral tissue to attenuate the Xray beam
- Cancer risk is cumulative with multiple exposures
- Longer lifetime for radiation effects to manifest

Effective Dose Estimates for a 5 year old child

Karen Thomas Hospital for Sick Children, Toronto
### Effective Dose (ED)

- It is a radiation dose quantity
- It is a computation based on:
  - Organ dose and radiosensitivity
  - Weighting factors
- It is not a risk number

### ED - DLP METHOD

- Scanner generated CT dose index (CTDI) and Dose length product (DLP)

#### 3.4YO 14.2Kg F routine chest CT

80kVp; ref mAs 55; mean mAs 122

CTDI vol 2.21. Conversion to 16cm phantom (x2) = 4.42

DLP = CTDIvol x scan length = 43 (16 cm conversion = 86)

### ED for Chest CT - DLP METHOD

- Scanner DLP multiplied by an age based pediatric correction factor

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1yr</td>
<td>-0.037</td>
</tr>
<tr>
<td>1–4yrs</td>
<td>-0.026</td>
</tr>
<tr>
<td>5–9yrs</td>
<td>-0.018</td>
</tr>
<tr>
<td>10–14yrs</td>
<td>-0.013</td>
</tr>
<tr>
<td>&gt;14yrs</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

3.4YO F – DLP of 86; ED = 86 x 0.026 = 2.23 mSv

### Updated Chest DLP Conversion Factors

( based on Radiation Protection Publication 103 updated organ radiosensitivity)

- For ages:
  - < 1yr: -0.057
  - 1-4yrs: -0.038
  - 5-9yr: -0.026
  - 10-14yr: -0.019
  - Adult: -0.02

- For exposure:
  - 3.4YO F – DLP of 86; ED = 86 x 0.038 = 3.26 mSv

### Approximate Medical Radiation Doses and chest Xray equivalents

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Dose (mSv)</th>
<th>CTDIvol Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDG PET</td>
<td>1.6</td>
<td>1/14th Fli</td>
</tr>
<tr>
<td>2-view chest</td>
<td>0.02</td>
<td>1</td>
</tr>
<tr>
<td>Tc-99m radionuclide gastric emptying</td>
<td>0.06</td>
<td>3</td>
</tr>
<tr>
<td>Tc-99m radionuclide cystogram</td>
<td>0.18</td>
<td>9</td>
</tr>
<tr>
<td>Tc-99m radionuclide bone scan</td>
<td>up to 6.2</td>
<td>310</td>
</tr>
<tr>
<td>FDG PET</td>
<td>15.3</td>
<td>765</td>
</tr>
<tr>
<td>Fluoroscopic cystogram</td>
<td>0.33</td>
<td>16</td>
</tr>
<tr>
<td>Upper GI</td>
<td>3</td>
<td>150</td>
</tr>
<tr>
<td>Contrast enema</td>
<td>7</td>
<td>350</td>
</tr>
<tr>
<td>Chest C</td>
<td>up to 3</td>
<td>150</td>
</tr>
<tr>
<td>Abdomen C</td>
<td>up to 5</td>
<td>250</td>
</tr>
</tbody>
</table>

- Airline passenger (coast to coast R/T): 0.03 mSv
- Flight crew / attendants/yr: 1.6 mSv

### Disadvantages:

- Correction factors for 120kVp
- Correction NOT scanner specific
- Large age/size range

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Huda, W. Pediatric Radiology 2002; 32; 272-279
Optimization of benefit/risk ratio

• Appropriate to do exam
• Appropriate timing of exam
• Appropriate modality
• Get clinician/radiologist together
• Technologist

CT is a digital technology, unlike radiographs, excessive radiation dose does not produce overexposed or poor quality images

• 40 to 80% reduction of typical adult CT doses still produces high quality diagnostic scans in children and young adults

CT DOSE and REDUCTION STRATEGIES

CT vendor related

• MDCT > radiation
• Overranging – region above and below prescribed scan are exposed to radiation, can contribute 10% increase to dose. Therefore try and do multiple contiguous parts as single sweep e.g. CAP
• “auto” MA and automodulation of MA (changing MA during scan based on tissue thickness/density). Choose high detail option (lower noise index or higher ref mAs) - increased dose
• Many newer scanners provide some suggested pediatric protocols
• Imager still needs to choose many parameters to optimize study.

CT DOSE REDUCTION

SPECIFIC PARAMETERS

• kVp (80 to 120 kVp)
• mAs (40 to 180)
• GANTRY CYCLE TIME (0.3-0.5 secs)
• PITCH (5-1.5) - Function of table speed and width of xray beam
• mAs = mA x gantry rotation time (Siemens scanner incorporates pitch in mAs)
• DETECTOR THICKNESS (.6 & 1.2mm)
• Differences with varying manufacturer, e.g. Siemens has increased beam filtration, 40mAs on Siemens64 equivalent to 23mAs on GE64

• Kilovoltage ( kVp)
• SINGLE MOST EFFECTIVE DOSE REDUCTION STRATEGY
• Typical 80 to 140 kVp for CT
• Exponential dose relationship (decrease kVp from 120 to 100 - dose decreased 39%)
Decreased kVp produces increased contrast but also increased noise
Decrease kVp (80 to 100kVp) in small children and high contrast studies e.g. CTA, Musculoskeletal
LPCH CHEST CT Results - 2006 to 2008
major change was 120kVp to 80 or 100kVp

- <15 kg, CTDI vol, DLP, and ED were reduced by 73%, 75% and 73% respectively
- 15-60 kg, CTDI vol, DLP, and ED were reduced by 45%, 44% and 48% by using 2008 protocol
- All of these dose reductions were statistically significant
- Objective noise measurements and subjective quality assessments were still acceptable

3 years / boy, 14.7 kg, 2006 - 120kVp
4 years / boy, 14.1 kg, 2008 - 80kVp

CT DOSE REDUCTION
SPECIFIC PARAMETERS

- mA
  - Linear relationship: 1/2 mA = 1/2 DOSE
  - Decreased mA – increased noise
  - Most pediatric scans should be in the 40 to 180 mA range depending on:
    - weight
    - site (higher for brain and abdomen than chest and extremities)
    - slice collimation (thinner slice selection often defaults to a higher mA)
    - detail required (less for larger lesion, f/u scan, planning scan e.g. precontrast)

15 mAs
GE

CT DOSE REDUCTION
SPECIFIC PARAMETERS

- Gantry cycle time (0.3 - 1.0 sec) x mA = mAs
- Linear relationship also: 1/2 time = 1/2 dose
- Faster scan useful:
  - less need for sedation
  - decreased motion artefact
- Increased noise with decreased spatial resolution

CT DOSE REDUCTION
SPECIFIC PARAMETERS

- PITCH
  - This is a function of table speed and width of the Xray beam
  - More complex parameter in multidetector scanners
  - Lower pitch produces higher image quality and higher radiation dose
  - In general a higher pitch (around 1-1.5) is fine for most pediatric scans. <1 pitch if high detail is required.
  - Note – some scanners automatically increase mA to adjust for higher pitch
DETECTOR WIDTH
- .6mm or 1.2mm
- Thinner detector increases dose approx. 20%, use for high detail scan e.g. CTA.

SLICE GAPS
- Slice gaps e.g. HRCT 1mm thick slices every 5-10mm can reduce dose by 50% to 80% versus contiguous or volumetric scanning, although there is a tendency to significantly increase mA in HRCT scans to increase resolution and decrease noise. Some scanners increase mA automatically with decreased slice thickness &/or cannot obtain a single slice at each selected level.

EKG GATED CT
- Marked increased radiation dose.
- 4 to 5X nongated CTA
- Multiple slices at each level throughout the cardiac cycle
- Requirement for thin collimation, low pitch for highest spatial resolution of small structures (coronaries)

SPECIFIC DOSE REDUCTION STRATEGIES
Protective Shields
- Reusable or disposable protective shields of different sizes available for breast, thyroid, eyes
- Thin 2-ply bismuth strip with underlying foam pad placed anteriorly
- Attenuates the xray beam, especially the low energy rays. Foam pad absorbs scatter
- Does not completely block x-rays but decreases breast dose by about 20-30%
- Causes some increased noise but can still be used effectively even in very low dose protocols
GENERAL CT DOSE REDUCTION STRATEGIES

- Tailor the CT to best answer the clinical questions. COMMUNICATION
- Limit location to area of interest e.g. heart only. Avoid radiosensitive organs where possible e.g. thyroid
- Avoid "routine" multiple series e.g. pre and post contrast scans or both arterial and venous phase imaging
- Delayed images only when necessary e.g. renal trauma. Limit location
- Scanning two or more phases is the same as obtaining multiple separate scans

- There is a tendency to quickly adopt adult practices and protocols in children.
- Particularly occurs in situations where there is overlap care, such as in many ER’s.

- PEDIATRIC DISEASE PATTERNS DIFFER FROM ADULTS
- ORDERING AND PERFORMING IMAGING STUDIES SHOULD LIKewise BE SPECIFIC TO THE CLINICAL CONCERN, SIZE OF THE CHILD AND BODY PART SCANNED

14 YO M ATV ACCIDENT
NORMAL CT
ABDOMEN(OUTSIDE), HEAD, FACIAL, ENTIRE SPINE

3yo Abdominal pain
EARLY
DELAY
NONACCIDENTAL INJURY

TRAUMA SERIES

40mAs
Small
Post dislocation lt clavicle
Comp lt IV

EST. ED >20mSV
Future CT Capability

- 128/256 detectors
- Chest CT<1sec, dose much lower
- kVp As well as mAs automodulation, Lower kVp - 70
- Organ based dose modulation- Xray turned off anteriorly over breasts
- Adaptive collimator control- shields area above and below desired scan location (overranging)
- Iterative reconstruction with noise reduction
- Cardiac CT, prospective gating with dose modulation or EKG triggering. Flash dual source scan within 1 heartbeat (.25secs) Much faster, much lower dose
- Dual source- faster scan, tissue differentiation, virtual noncontrast

SUMMARY

- Many people and technical factors need to work together to improve and optimize CT imaging in children
- Important not to treat children as little adults
- Customize protocols that are appropriate for children and follow them
- ALARA is the guiding principle for all imaging techniques involving ionizing radiation. Always aim for high quality study at lowest dose
- Dose saving capability only effective if you use them
- BE AN ADVOCATE FOR THE CHILD

Question study requests or protocols that appear unusual

Question orders to do multiple sequences or follow adult protocols