SPECIFIC PRINCIPLES FOR DOSE REDUCTION IN HEAD CT IMAGING

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Harvard Medical School
OUTLINE

• 1st Presentation:
  • Dose optimization strategies
  • Routine Head CT protocols

• 2nd Presentation:
  • What we need to see?
  • Effect of parameters and image review
  • Some newer tricks using Dual Energy CT
STRATEGY: MAKE SURE THAT EACH SCAN IS JUSTIFIED
MAKE SURE EACH SCAN IS JUSTIFIED

- Even a low-dose CT is too much dose when inappropriately ordered
- Check with physician if in doubt; Triage when appropriate
- About 1/3rd of CT are inappropriate!
  - Brenner, NEJM 2008
Radiology Order Entry

Select a hospital to work with:

- Mass General Hospital
- Newton Wellesley Hospital

Authentication Required

Enter username and password for http://mghroe

User Name: 
Password: 
OK  Cancel
ROE: SELECT A MODALITY AND A BODY PART

Courtesy of Sarabjeet Singh, MD
To order a CTA exam please select it from CT drop-down menu.

### Exam Requested

<table>
<thead>
<tr>
<th>Exam Request / Protocol</th>
<th>Includes the following examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT Head</td>
<td>CT Head or Brain</td>
</tr>
<tr>
<td>CT Head &amp; Neck</td>
<td>CT Head or Brain and CT Neck</td>
</tr>
<tr>
<td>Pediatric Head for Craniosynostosis</td>
<td>CT Head or Brain without contrast and 3D reconstructions</td>
</tr>
<tr>
<td>Pediatric Head for Trauma</td>
<td>CT Head or Brain without contrast</td>
</tr>
<tr>
<td>CT Base of Skull</td>
<td>CT Base of Skull</td>
</tr>
</tbody>
</table>

### Protocol

- 3D

### Intravenous Contrast

- Contrast use at Discretion of Radiologist
- Do not use contrast
- Use contrast

Courtesy of Sarabjeet Singh, MD
### ROE: ENTER SIGNS AND SYMPTOMS

Select at least one box from either of the following groups:

#### Signs / Symptoms
- Acromegaly
- Speech changes (or Aphasia), new or progressive
- Concussion mild or moderate acute, no neurological deficit
- Coordination changes, new or progressive
- Dementia
- Head injury mild or moderate acute, no neurological deficit
- Headache
- Hyperprolactinemia
- Pain in face
- Weakness- right side / left side / both
- Acute visual deficit (other than photophobia and aura)
- Syncope/fainting
- Signs of meningeal irritation (such as stiff neck)

#### Known Diagnoses (not rule/out!)
- Aneurysm

- Ammonorrhea
- Abnormal gait (Ataxia)
- Seizures new or progressive
- Cranial nerve palsy (specify):
- Dizziness
- Head injury moderate or severe acute, stable
- Hearing changes
- Mental Status change (after trauma)
- Sensation loss
- TIA with transient neurological disturbance
- Mass or lump
- Vision changes
- Signs of increased intracranial pressure (such as fundoscopic exam)
- Decreased alertness

- Arterial-venous malformation (AVM)

Courtesy of Sarabjeet Singh, MD
ROE: SHOWS PREVIOUS EXAMS

The patient had 4 previous CT Scans (more info) at Partners Imaging Centers.

Click ‘OK’ to proceed to order the exam or ‘Cancel Exam’ to cancel the exam.

Courtesy of Sarabjeet Singh, MD
ROE: EVIDENCES-BASED APPROPRIATENESS

Head CT is indicated for the clinical indications provided

Options:
- Proceed with exam
- Cancel or select new exam
- Change indications and resubmit

Alternate procedures to consider:
MR:

PATIENT NAME: TEST, IGNORE
DOB: 03/09/1973  Gender: M
MRN: 0000006
ORDERING PHYSICIAN: Gupta, Rajiv

Clinical Consultation
ROE Help
Managing and Creating Templates

Courtesy of Sarabjeet Singh, MD
Select Site and Schedule Exam

Location | Search Calendar | First Available
--- | --- | ---
Boston-Main Campus | Thu 3/7/2013 5:46 PM | Schedule
Boston-Yawkey Cantor | Fri 3/1/2013 4:00 PM | Schedule
Chelsea | Tue 2/26/2013 1:00 PM | Schedule
Danvers (MGH/NS) | Wed 2/27/2013 3:00 PM | Schedule
Waltham | Tue 2/26/2013 1:45 PM | Schedule
Worcester | Tue 2/26/2013 1:15 PM | Schedule
Nantucket Cottage Hospital | Tue 2/26/2013 2:00 PM | Schedule

stress - 7.36.4

- Contrast use at Discretion of Radiologist
- CT Head

- Head injury mild or moderate acute, no neurological deficit - 959.01

Gupta, Rajiv
ss272 (Site: MGH) 2/26/2013 11:05 AM

To schedule or reschedule multiple exams select up to 3 above.
DECISION SUPPORT: EFFECT ON VOLUME

*Sistrom et al. Radiology 2009*

- Appropriateness for CT is not optional!
- Decision support and practice guidelines help.
STRATEGY: ACQUIRE EACH SCAN WITH CARE AND LOVE
CT Tech is the #1 determinant of Image Quality
TECHNOLOGIST’S RESPONSIBILITIES

- Patient Positioning
  - Centering, Positioning in the head-holder
  - Removing extraneous hardware and wires
- Patient instructions: Breathing and Movements
- IV access, injection, monitoring

- Delimited low-dose scout
- Appropriate protocol
- Transverse CT images
  - FOV
  - Scan range
  - Scan parameters
- Appropriate recons
GANTRY ANGULATION FOR HEAD CT

- Reduces eye lens dose by 87%.
- Instead of OM line- skull base to sup. orbit: angulate
- Non flexed head should do the same without gantry tilt
Off-centering and Radiation

- 95% patients are off-centered in CT
- Dose up by 3-30% due to bow tie

Noise increase 30%
Effecive mA loss 70%

Off centering Noise
Noise increase 30%

{
30 x 21.5 cm phantom
Elliptical phantom

Votes: Toth et al. SPIE 2006

Effective mA loss 50%

CENTERING, SCOUT AND SERIES RECONS

- Good patient centering means good AEC and image quality
- Scout tailored to the clinical question and really low-dose:
  - 80kVp, 20-40mAs sufficient
  - Targeted and focused
- Scan series
  - Minimum required
  - When multiple - dose should not be multiple folds higher
- Scan length and FOV: Targeted and focused
GOOD SCANNING PROTOCOLS

• Beam collimation: Lower is better (16*0.6 >> 16*1.2)
  • Pros: Less scatter
  • Pros: Better slice selectivity profile
  • Cons: More rotations
  • Cons: Slight dose penalty

• Rotation speed: Fast to minimize motion artifacts

• Reconstruction kernel
  • Softer: thinner slices (CTA) or lower dose
  • Sharper: Bones
STRATEGY: OPTIMIZE TUBE CURRENT AND USE TUBE CURRENT MODULATION
OPTIMIZE TUBE CURRENT

• Lowest possible mAs is proportional to:
  • Degree of intrinsic tissue contrast
  • Acceptable level of image noise
  • Noise ~ 1 / SQRT (mAs)

Michael Lev, MGH
50% REDUCTION?: SLIGHTLY NOISIER, BUT OK FOR FOLLOW-UP

- Department wide study ↓ mA by 50%:
  - Unchanged HU, GW conspicuity
  - 22% decreased CNR (attributable to noise)

ADAPTIVE TUBE CURRENT MODULATION

- Varies mA both in radial and axial direction
- Substantial dose reductions have been reported
  - % decrease depends on baseline protocol
    - Smith, Dillon, Wintermark et al. Radiology 2008
- More effective in neck than head
  - Wide range of thickness in shoulders
  - Noise index values of 11.4 and 20.2, result in 20% and 34% dose reduction, respectively
    - Russell, Anzai et al, Seattle. AJNR 2008
OTHER CONSIDERATIONS

- Lower kV
  - Increased photoelectric effect
  - Higher HU iodine
- Avoid rescanning same region
  - E.g., head and temporal bone, face and sinuses (? billing)
- Maximize quality parameters
  - Remove extraneous hardware
  - Optimize contrast bolus; right sided
  - Angle gantry though clips, fillings

*Brown, Lustrin, Lev, Taveras et al. AJR 1999*
AXIAL VS HELICAL: CONVENTIONAL WISDOM

Axial
- Pros: Better IQ
  - No windmill artifact
- Pros: Lower Dose
- Cons:
  - No coronal/sagittal view
  - No thin slices with arbitrary recon interval

Helical
- Cons: Lower IQ
  - Windmill artifact
- Cons: Higher dose
- Pros:
  - Coronal/sagittal view
  - Thin slices with arbitrary recon interval
The image quality of thinly collimated spiral CT of the brain with image combining is at least as good as that of thickly collimated sequential CT and, in some aspects, better. The
LENS DOSE

• Tilt matters
  • Possible only in axial mode
• mA modulation matters
• More slices are better (64 > 16)

Tan et al, AJNR 2008
AXIAL VERSUS HELICAL

- At MGH, we do helical
  - Quick, MPR, no IQ differences
  - Dose: Average CTDI vol = 45 - 60 mGy
  - Artifacts: Can read through them
  - Disadvantage: gantry tilt and eye dose

- Others prefer Axial scanning
  - Advantages: lower dose to lens, gantry tilt
  - Disadvantages:
    - Slower
    - Motion artifacts
    - No MPR
ADAPT SCAN PROTOCOL TO THE CLINICAL SITUATION AND INDICATION

- Tailor protocol to clinical question, e.g.:
  - 30 mAs for sinus CT, FESS planning;
  - 30 mAs for pituitary CT, transphenoidal sx

Sample Neuro Protocols
- Routine head
- CTA head
- Perfusion CT
- Temporal bone CT
- Paranasal sinuses CT
- CT angiography
- Spine CT

Mulkens et al, AJR May 2005
Loubele et al, Radiat Prot Dosimetry 2005
CRANIOSTENOSIS
80KVP; 60 MA, P1.4
0.04 MSV= 0.08MSV
POST TRAUMA 120 KVP, 0.984 P 90-140 MA 5NI 5MM-2.5MM

<table>
<thead>
<tr>
<th>Type</th>
<th>Scan Range (mm)</th>
<th>CTDIvol (mGy)</th>
<th>DLP (mGy cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scout</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Helical</td>
<td>129.250-5130.750</td>
<td>22.12</td>
<td>400.89</td>
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</tbody>
</table>
SINUS AND ORBITS

<table>
<thead>
<tr>
<th>Orbit, face, and sinus CT protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Series</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**MGH: 120 kVp, 50 mAs, 0.9 pitch, limited coverage**

<table>
<thead>
<tr>
<th>Temporal bone CT protocol</th>
</tr>
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<tbody>
<tr>
<td><strong>Series</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
STRATEGY: USE ITERATIVE RECONSTRUCTION WHEN AVAILABLE
Iterative Reconstruction Algorithms

ASIR (GE), IRIS, SAFIRE (Siemens):
(MBIR --- Model Based Iterative Recon)

Improved Image Quality, Lower Dose

Courtesy of Shervin Kamalian, MD
Normal case: ASIR vs no ASIR

CDTIVol: 28.82 mGy
DLP: 522.47 mGy.cm
Effective Dose: 1.09 mSv
(Conversion factor 0.0021)

Courtesy of Dr. Pomerantz & Kamalian, MGH
## SAMPLE CT DOSE REDUCTION AT 30% ASIR

<table>
<thead>
<tr>
<th>Head I.&amp;I+</th>
<th>kv</th>
<th>mA</th>
<th>Noise (ADM)</th>
<th>ASIR</th>
<th>Rot speed</th>
<th>Pitch</th>
<th>CTDIvol</th>
<th>DLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>120</td>
<td>200</td>
<td>30%</td>
<td>0.7</td>
<td>0.531:1</td>
<td>49.7</td>
<td>932.25</td>
<td></td>
</tr>
<tr>
<td>previous</td>
<td>120</td>
<td>250</td>
<td>0%</td>
<td>0.7</td>
<td>0.516:1</td>
<td>66.51</td>
<td>1270.34</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CTA (Head)</th>
<th>kv</th>
<th>mA</th>
<th>Noise (ADM)</th>
<th>ASIR</th>
<th>Rot speed</th>
<th>Pitch</th>
<th>CTDIvol</th>
<th>DLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>120</td>
<td>235</td>
<td>30%</td>
<td>0.5</td>
<td>0.531:1</td>
<td>41.18</td>
<td>733.57</td>
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</tr>
<tr>
<td>previous</td>
<td>120</td>
<td>350</td>
<td>0%</td>
<td>0.5</td>
<td>0.516:1</td>
<td>59.62</td>
<td>1170.17</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>CTA (H&amp;N)</th>
<th>kv</th>
<th>mA</th>
<th>Noise (ADM)</th>
<th>ASIR</th>
<th>Rot speed</th>
<th>Pitch</th>
<th>CTDIvol</th>
<th>DLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>120</td>
<td>min 350 max 600</td>
<td>13</td>
<td>30%</td>
<td>0.5</td>
<td>0.984:1</td>
<td>29.89</td>
<td>1333.86</td>
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<tr>
<td>previous</td>
<td>120</td>
<td>min 350 max 600</td>
<td>10</td>
<td>0%</td>
<td>0.5</td>
<td>0.516:1</td>
<td>57.06</td>
<td>2518.04</td>
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</table>

<table>
<thead>
<tr>
<th>HD</th>
<th>kv</th>
<th>mAs (ADM)</th>
<th>ADM Noise</th>
<th>ASIR</th>
<th>Pitch</th>
<th>Rotate speed</th>
<th>CTDIvol</th>
<th>DLP</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>C spine</td>
<td>140</td>
<td>Min 100 Max 715</td>
<td>11.83</td>
<td>30%</td>
<td>0.561:1</td>
<td>0.5</td>
<td>21.45</td>
<td>539.08</td>
<td>2.5</td>
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<tr>
<td>T/L spine</td>
<td>140</td>
<td>Min 100 Max 715</td>
<td>10</td>
<td>30%</td>
<td>0.984:1</td>
<td>0.5</td>
<td>10.11</td>
<td>246.59</td>
<td>0.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VCT</th>
<th>kv</th>
<th>mAs (ADM)</th>
<th>ADM Noise</th>
<th>ASIR</th>
<th>Pitch</th>
<th>Rotate speed</th>
<th>CTDIvol</th>
<th>DLP</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>C spine</td>
<td>140</td>
<td>Min 100 Max 715</td>
<td>20</td>
<td>0%</td>
<td>0.561:1</td>
<td>0.5</td>
<td>42.04</td>
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<tr>
<td>T/L spine</td>
<td>140</td>
<td>Min 100 Max 715</td>
<td>20</td>
<td>0%</td>
<td>0.561:1</td>
<td>0.5</td>
<td>77.92</td>
<td>1860.57</td>
<td>0.6</td>
</tr>
</tbody>
</table>
SAMPLE MGH 64-SLICE HEAD CT PROTOCOL
(MINOR VARIATIONS BETWEEN SCANNERS)

<table>
<thead>
<tr>
<th>Series Auto Transf</th>
<th>OFF</th>
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<tbody>
<tr>
<td>Mode</td>
<td>Helical</td>
</tr>
<tr>
<td>Time</td>
<td>0.7</td>
</tr>
<tr>
<td>DMPR</td>
<td>ON</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.25</td>
</tr>
<tr>
<td>Pitch</td>
<td>0.531:1</td>
</tr>
<tr>
<td>Speed</td>
<td>10.62</td>
</tr>
<tr>
<td>Interval</td>
<td>0.625</td>
</tr>
<tr>
<td>Rotation Time</td>
<td>0.7</td>
</tr>
<tr>
<td>Gantry Tilt</td>
<td>0</td>
</tr>
<tr>
<td>SFOV</td>
<td>Head</td>
</tr>
<tr>
<td>KV</td>
<td>120</td>
</tr>
<tr>
<td>mA</td>
<td>250</td>
</tr>
<tr>
<td>DFOV</td>
<td>22</td>
</tr>
<tr>
<td>ALG</td>
<td>Standard</td>
</tr>
</tbody>
</table>

Recon 2:
5 MM DX STD AXIALS

| Thickness | 5.0   |
| Interval  | 5.0   |
| Algorithm | 22    |
| DFOV      | Std   |

Recon 3:
2.5 MM DX BONE AXIALS

| Thickness | 2.5   |
| Interval  | 2.5   |
| Algorithm | Bone  |
| DFOV      | 22    |

Helical, 120kV, Auto-mA, Pitch 0.5, ST 1.25, interval 0.625

DECRAD CODE: CTBR-
Send dose report to PACS
Earlier protocol: No ASIR, fixed tube current
CTD1vol: 67 mGy
Effective dose: 2.6 mSv

Optimized protocol: with ASIR and auto mA
CTD1vol: 31.6 ± 4.1 mGy
Effective dose: 1.2 ± 0.16 mSv  50% dose reduction

Last 50 patients CTD1vol with Optimized protocol
on CT 750 HD scanner

Courtesy of Drs. Pomerantz and Kamalian, MGH
TAKE HOME POINTS

- Justify each scan; Use another modality, when possible
- Mechanics: centering, wires, verbal instructions, etc.
- Minimize mA; use mA modulation
- 120kVp for routine; 80kVp for CTP, infants, and craniosynostosis
  - Use Auto-kV when available
- Configure protocol to clinical indication, Age, Size, prior scan hx, region
- Helical vs axial: Pros and cons; We prefer helical
  - Axial: > SNR for same settings
  - Helical: Multi-planar reformats; use thin collimation
- Avoid orbits, tilt gantry if needed
- Pediatrics: 125mA or lower; less than half the adult dose. Screen with CT, confirm with MRI
- Minimize variability
- Dose well below ACR guidelines