Neuro CT – What’s a Good Head Exam?

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Outline

• What we need to see?
• Routine Head CT protocols
• Dose optimization strategies
• Some newer tricks using Dual Energy CT
58 year old, new onset of neurologic symptoms

Where is the Abnormality?

CT: Equivocal for an infarct
Acute Infarct in the ACA territory

CT Angiography

CTA SI: Reduced perfusion

DWI
Requirements

- Good gray-white differentiation (8-10 HU)
Different Case: Young patient after trauma
Requirements

- Good gray-white differentiation
- Proper cupping correction
11 month old female that presented with gagging after trauma to oropharynx with drum stick.
Diagnosis

• Retropharyngeal abscess
  – Etiology
    • Suppurative bacterial lymphadenitis
      – S. aureus, Strep B, oral flora
    • Foreign body perforation
    • Trauma
Requirements

- Good gray-white differentiation
- Proper cupping correction
- Good soft tissue discrimination
44 year old fell from a tree
2 months later
Surgical Specimen

Take-home Points:
- Wood may appear as air
- Accurate HU calibration is important
Another Case: Pencil vs Globe
Requirements

• Good gray-white differentiation
• Proper cupping correction
• Good soft tissue discrimination
• Accurate, reliable HU calibration
Subtle right occipital fracture, only visible on thin slices, and sharp kernel
Requirements

- Good gray-white differentiation
- Proper cupping correction
- Good soft tissue discrimination
- Accurate, reliable HU calibration
- High spatial resolution and MTF
4 year old with 2 week history of headaches, abdominal pain, anorexia and vomiting. Recent antibiotics for sinusitis.

Artifact or Pathology?
Imaging 1 Week Later

CT w/ Contrast

T1 Post
Pathology: Burkitt Lymphoma

B-cell lymphoma
Beam Hardening

- Effective beam energy increases.
- Beam “hardens” as it penetrates.
- Higher E \( \Rightarrow \) lower \( \mu \).
- “Cupping artifact”
Requirements

- Good gray-white differentiation
- Proper cupping correction
- Good soft tissue discrimination
- Accurate, reliable HU calibration
- High spatial resolution and MTF
- Artifact-free posterior fossa and skull base
“The Chest X-ray of the Brain”

Must support quick, confident read.

Main Culprits

- Poor SNR
- Poor CNR
- Poor spatial resolution
  - Improper recon kernel
  - Improper protocol
- Artifacts
  - Motion
  - Scatter
  - Beam hardening
  - Windmill
  - …
### Sample MGH 64-slice Head CT Protocol
*(Minor Variations between Scanners)*

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<table>
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<tr>
<th>Recon 2: 5 MM DX STD AXIALS</th>
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<td>Algorithm</td>
<td>Algorithm Bone</td>
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<td>DFOV</td>
<td>Std</td>
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Reformats: Coronal Skull Auto w/DMPR

- DFOV 22
- Thickness 5.0
- Interval 2.5
- Window Head

DECRAD CODE: CTBR-

Send dose report to PACS
CT Dose Reduction Strategies

- Use another modality!
- Optimize acquisition
  - Tailor to clinical requisition
  - Lower technique
  - Minimize artifacts
  - Dual Energy acquisition
- Optimize reconstruction / post-processing
  - FBP vs newer “iterative reconstruction” kernels
  - Filters, e.g. metal streak reduction
- Optimize readout
  - Coronal Reformats
  - Optimal PACS display
  - Appropriate window/level settings

Michael Lev, MGH
Optimizing Dose: Basic Principles

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

• Tailor the protocol to the clinical question
  – E.g.: 30 mAs for sinus CT, FESS planning
    Mulkens et al, AJR May 2005
    Loubele et al, Radiat Prot Dosimetry 2005
  – E.g.: 30 mAs for pituitary CT, transphenoidal sx
50% mAs Reduction?
Slightly Noisier, but OK for F/U

- Dept wide study ↓ mA by 50% for all CT’s
  - Unchanged HU, GW conspicuity
  - 22% decreased CNR (attributable to noise)

Optimizing Dose: Adaptive mA 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 useful for neck than head, in our experience
  - 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
Optimizing Dose: 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**
  - Decrease motion artifact: speed, sedation
  - Remove extraneous hardware
  - Optimize contrast bolus; right sided
  - Angle gantry though clips, fillings

*Brown, Lustrin, Lev, Taveras et al. AJR 1999*
Iterative Reconstruction Algorithms
ASIR (GE), IRIS, SAFIRE (Siemens):
(MBIR --- Model Based Iterative Recon)

Improved Image Quality, Lower Dose

Courtesy of Shervin Kamalian and GE Healthcare
### Sample CT Dose Reduction at 30% ASIR

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Single vs Dual Energy CT

- A single CT Number (HU)
- Prior knowledge for material separation
- Unable to distinguish materials with same HU
  - Blood vs. dilute contrast
  - Blood vs. diffuse mineralization
  - Uric acid vs. Ca oxalate
  - Calcification vs. gouty tophus
Dual Energy Principles

- Total attenuation decreases with increasing energy
- Decrease is characteristic for each material
- Depends on photon energy and material density
- X-ray absorption depends on the inner electron shells
  - DECT is sensitive to atomic number and density
  - DECT is not sensitive to chemical binding

C. Leidecker, Siemens
## Dual Energy Systems

**Siemens: Dual Source CT (Definition)**
- Two X-ray sources, two detectors, simultaneous acquisition
- Operate one source at 80kV and the other at 140kV

**General Electric: Discovery Gemstone (HD-750)**
- Single Source, single detector, on a fast gantry
- Rapidly alternate the single tube between 80kV and 140kV
DECT: Pro and Cons

Siemens: Dual Source CT (Definition)
- Simultaneous acquisition
- Optimized tube current
- Projections: 90 deg apart
- One detector smaller than other

General Electric: Discovery Gemstone (HD-750)
- Projections close to each other in time => separation in projection domain
- Tube current constant (i.e., not optimized for each kV).
Clinical Case

- 79 yo man with acute onset of right hemiparesis and aphasia
- Received IV t-PA at OSH
- Transferred to MGH for further management
- At MGH, CTA showed:
  - emboli in the distal left ICA
  - occlusion of left M1
Cath Lab: Recanalization
Post-op: 80kV and 140 kV Images
VNC and Iodine Overlay Images
Intra-parenchymal Hemorrhage

Single Energy

Iodine Overlay

Virtual Non-contrast

Follow-up Image
Virtual Monochromatic Images

- Are they clinically useful?
27 year-old male presents to ER complaining of sudden onset of severe right sided eye pain while using a weed whacker.
27 year-old after a weed whacker accident
Is the left optic nerve involved?
Metal artifacts, identical W/L setting

80 kV

140 kV
Monochromatic 190kV Images

The left optic nerve is spared!
Pre-Op CTA

- Nail entered the bony covering
- Carotid artery spared!
Post-Op CTA
Outcome

- Nail removed with globe intact
- Post-Op Evaluation:
  - Minor conjunctival laceration
  - No optic nerve injury bilaterally
  - 20/20 vision bilaterally!

☐ Take Home points:

- Dual-energy CT helps
- Wear Eye protection
MGH Head CT Take Home Points

- Dose well below ACR guidelines
- Configure protocol to the clinical need
- Avoid orbits if possible
  - Especially important in serial scans: ICU, pediatrics
  - But don’t sacrifice diagnostic accuracy!
- Pediatrics
  - 125 mA used, < HALF the adult dose
  - Strategy: screen with low dose CT, confirm with MRI
  - Age < 18
- Axial vs helical mode?
  - Axial, arguably, has > SNR for otherwise fixed settings
  - No real speed advantage to helical
  - Helical = more reformat/recon options (e.g., coronals)
- Dual Energy CT
  - Effective tool for material discrimination
  - Quantitative tool
  - Both sensitive and specific for Hemorrhage vs. Iodine
  - Limited by saturation and other artifacts