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

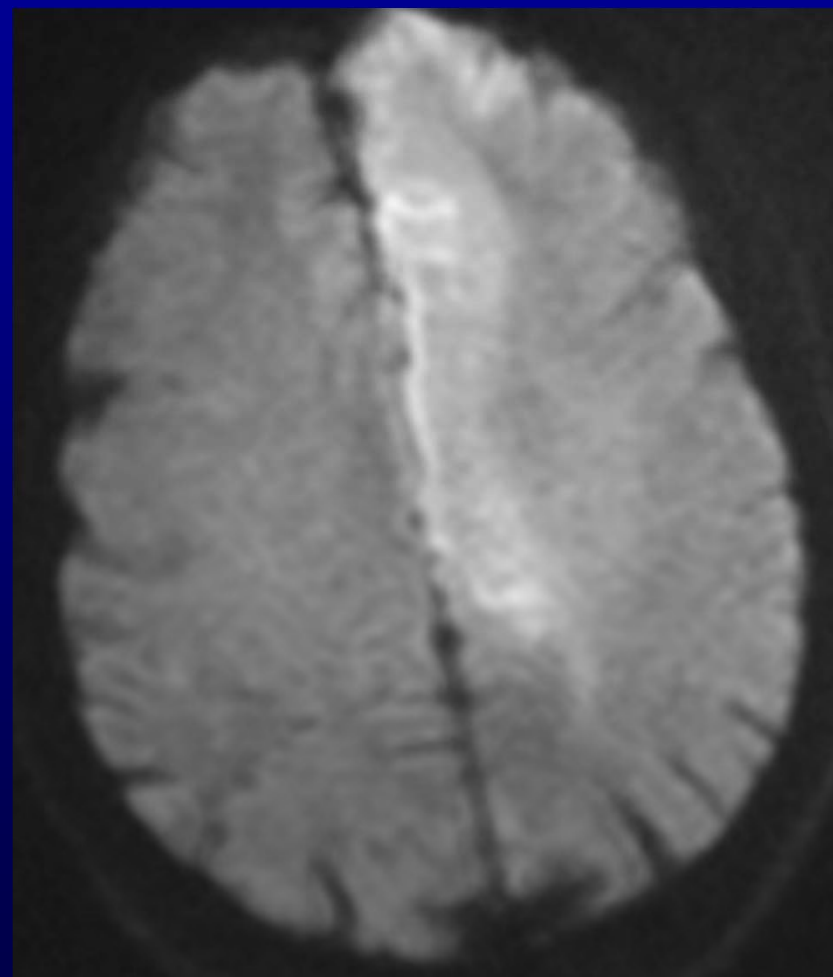
58 year old, new onset of neurologic symptoms

Where is the Abnormality?

CT: Equivocal for an infarct

Acute Infarct in the ACA territory

CT Angiography



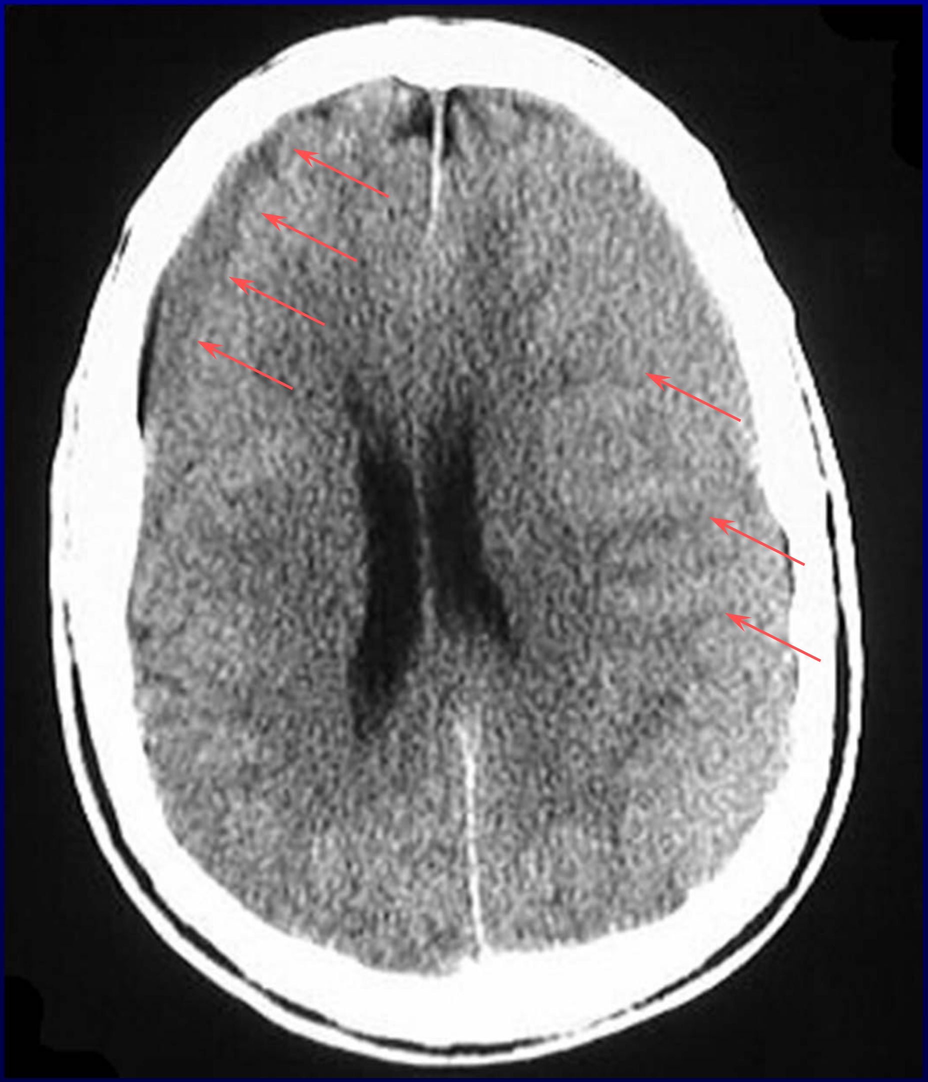
CTA SI: Reduced perfusion

DWI

Requirements

- Good gray-white differentiation (8-10 HU)

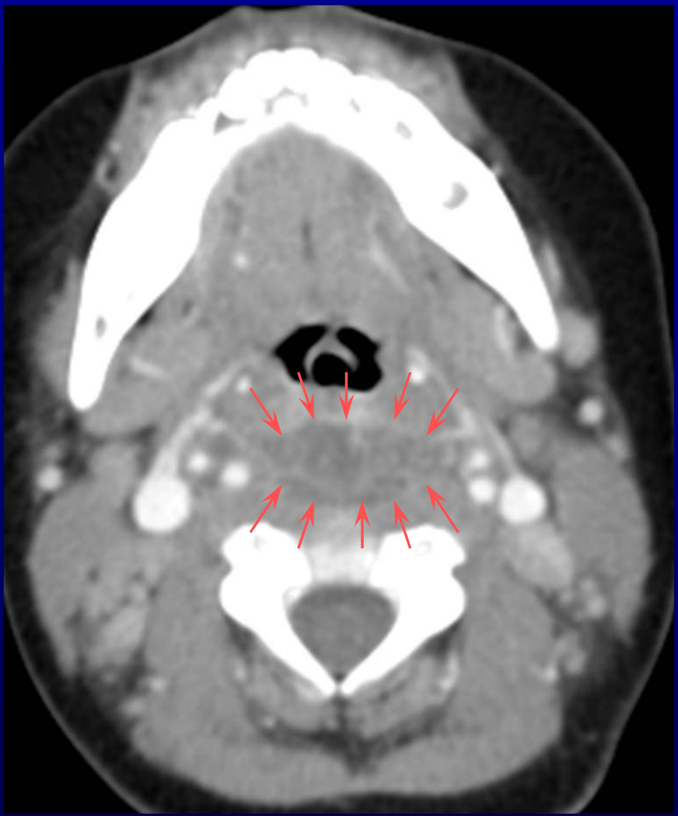
Different Case: Young patient after trauma

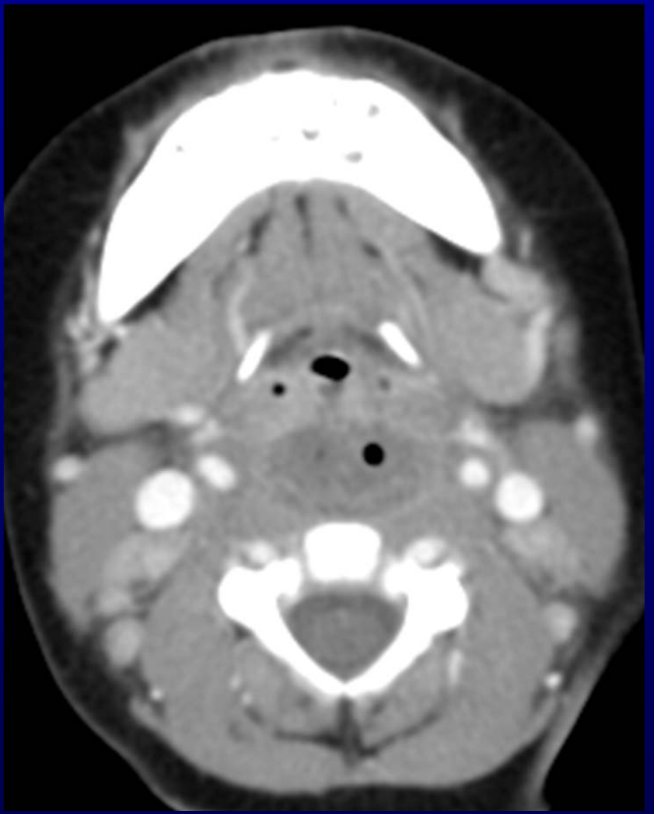


Requirements

- Good gray-white differentiation
- Proper cupping correction

11 month old female that presented with gagging after trauma to oropharynx with drum stick.





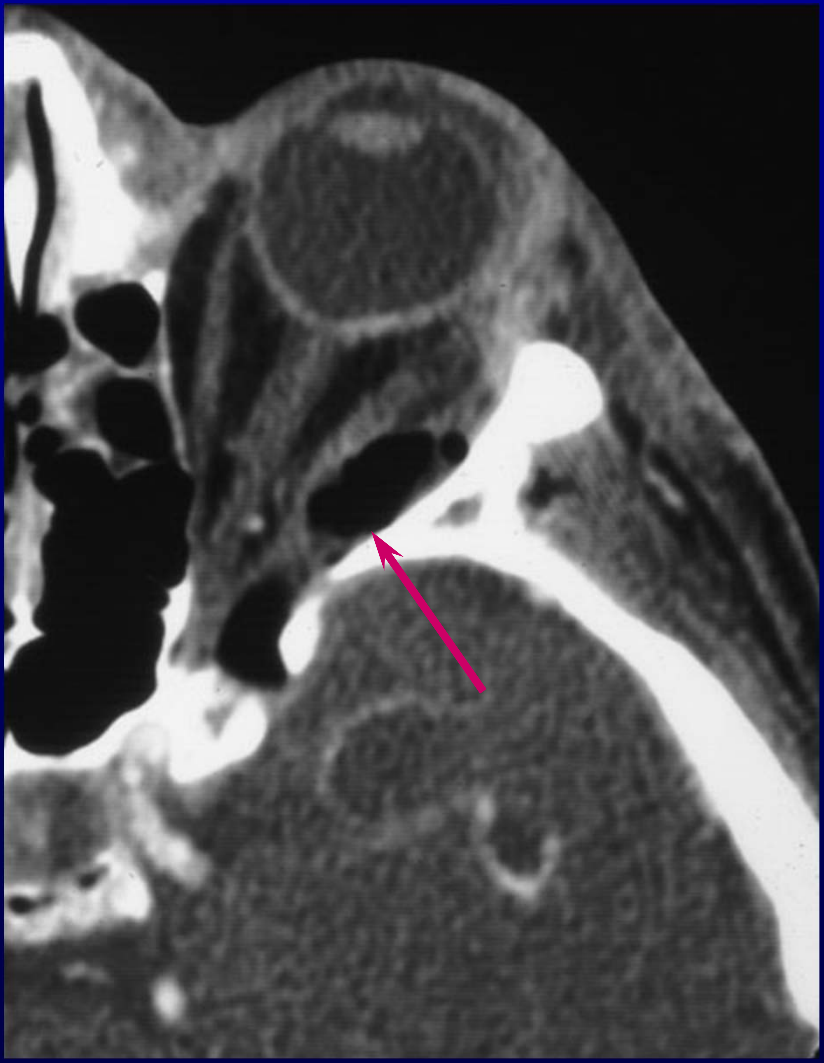
Diagnosis

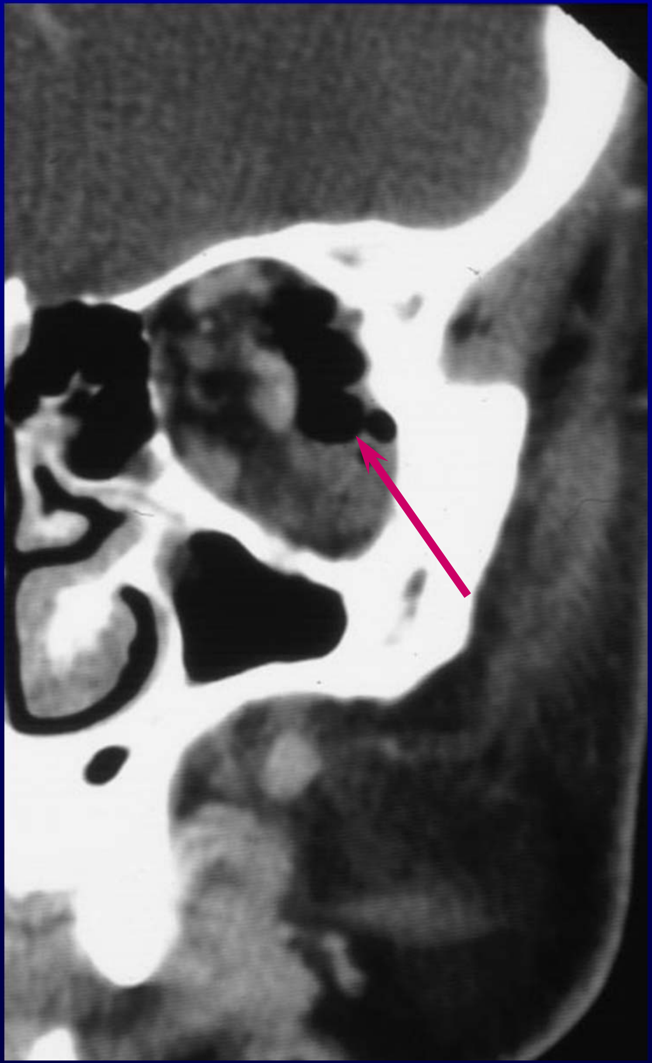
- Retropharyngeal abscess
  - Etiology
    - Suppurative bacterial lymphadenitis
      - S. aureus, Strep B, oral flora
    - Foreign body perforation
    - Trauma

Requirements

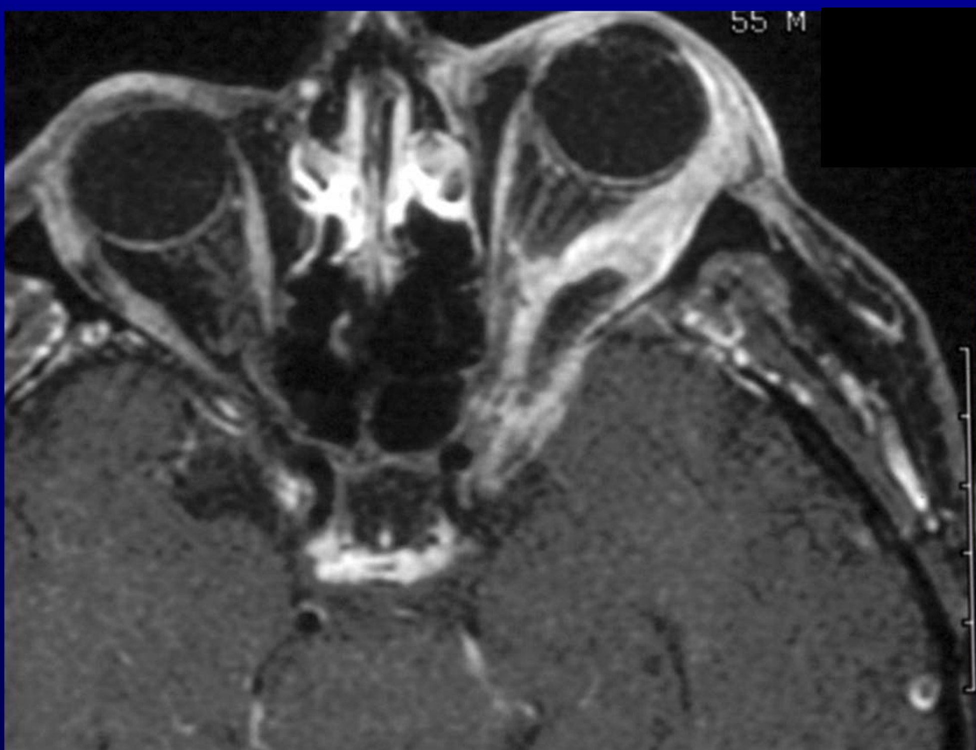
- Good gray-white differentiation
- Proper cupping correction
- Good soft tissue discrimination

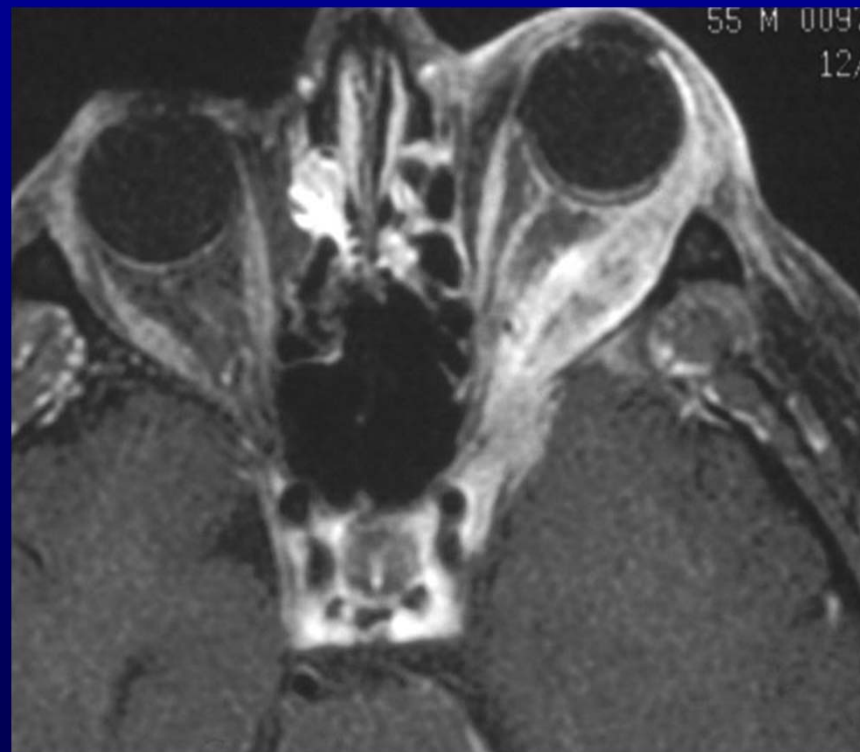
44 year old fell from a tree





2 months later





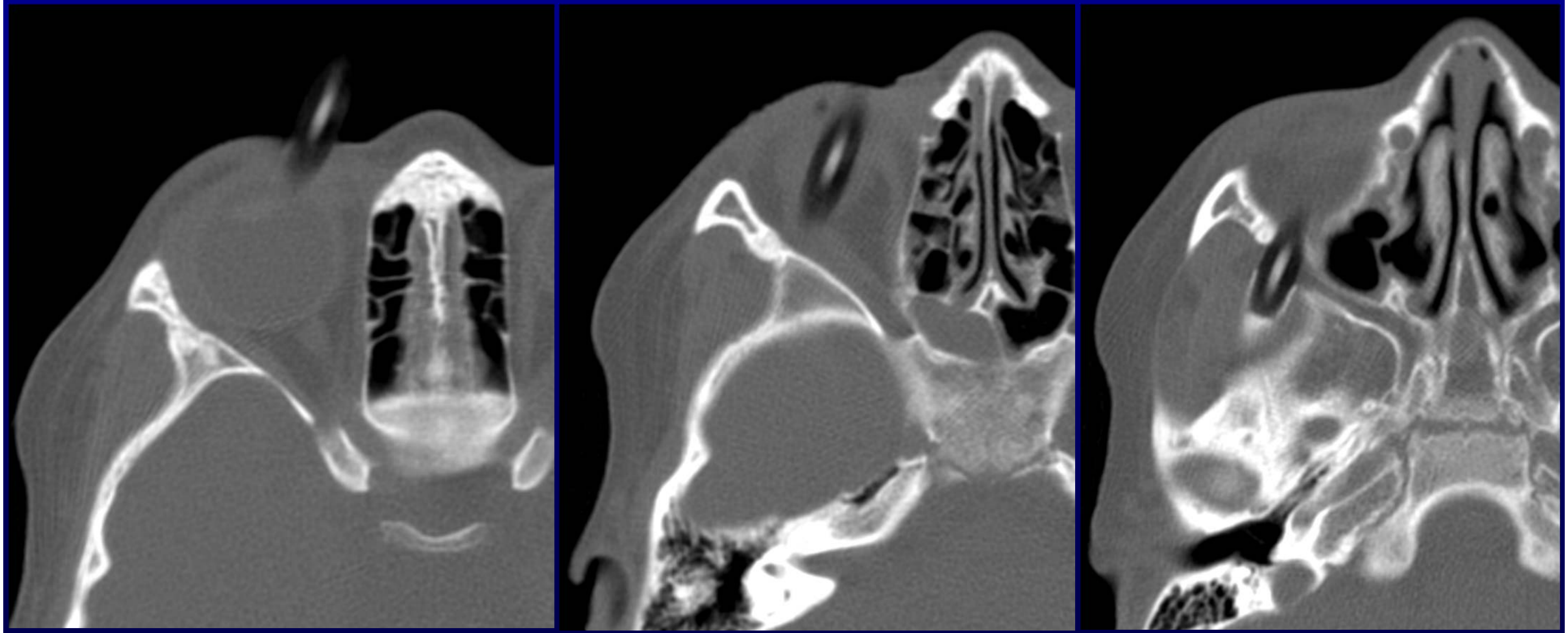
Surgical Specimen

Take-home Points:

- Wood may appear as air

- Accurate HU calibration is important

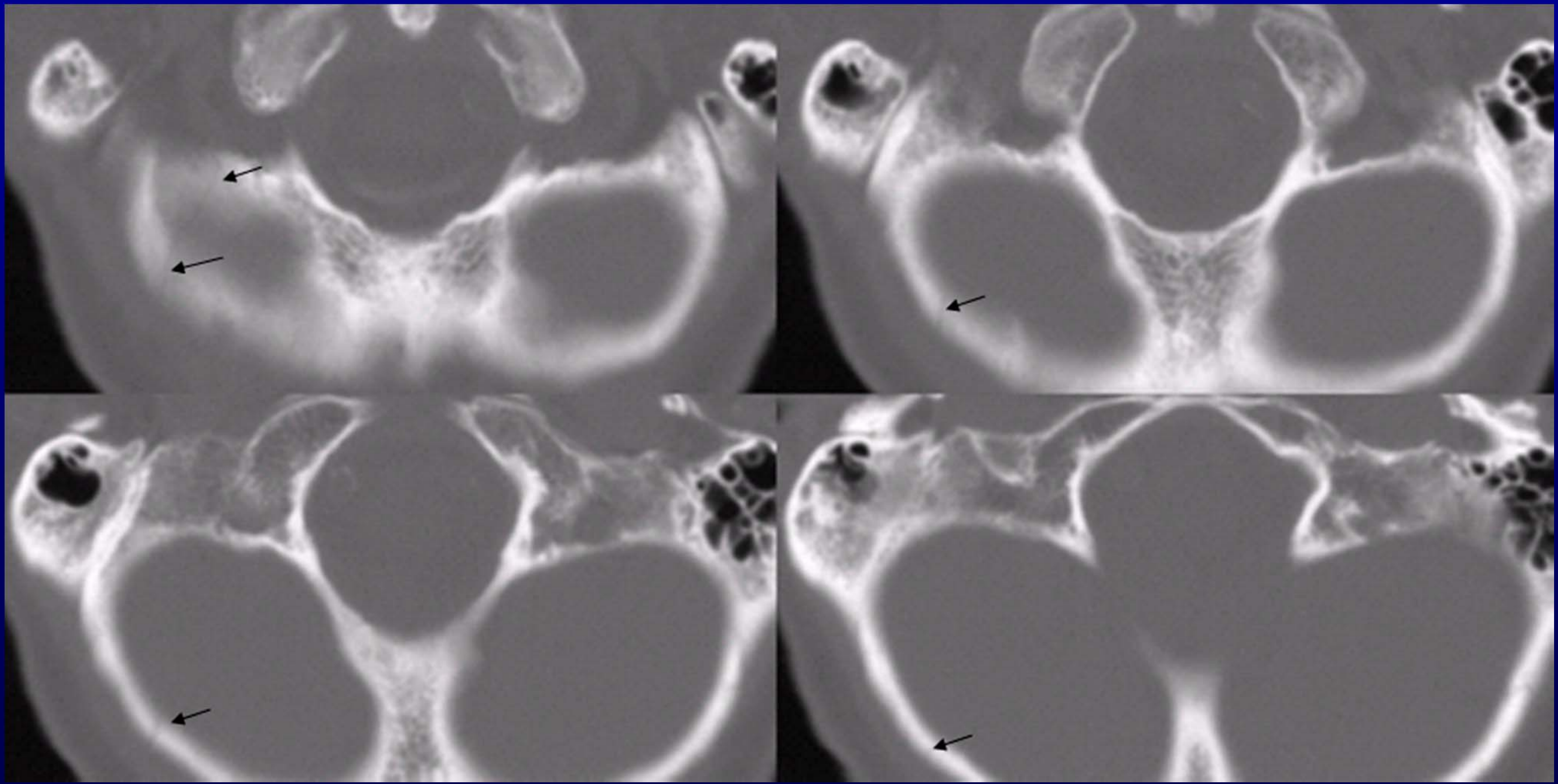
Another Case: Pencil vs Globe



Requirements

- Good gray-white differentiation
- Proper cupping correction
- Good soft tissue discrimination
- Accurate, reliable HU calibration

History of Trauma

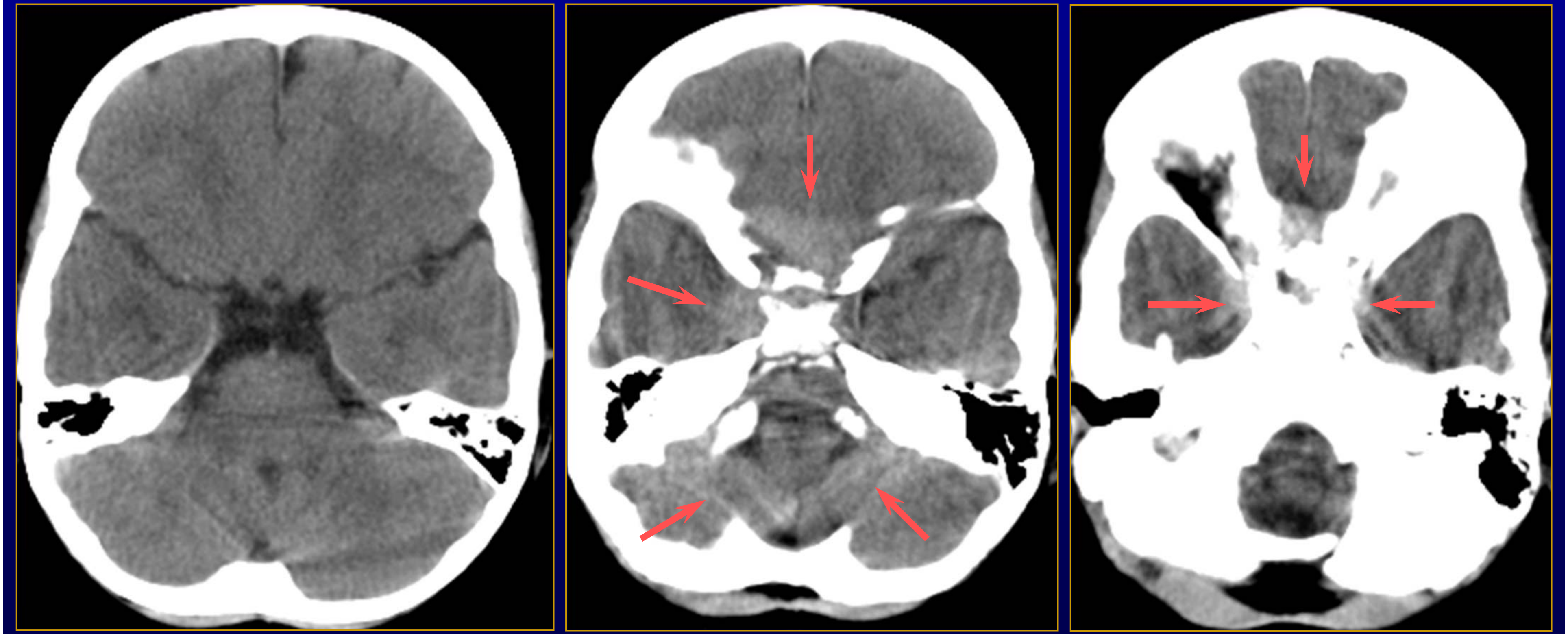


Subtle right occipital fracture, only visible on thin slices, and sharp kernel

Requirements

- Good gray-white differentiation
- Proper cupping correction
- Good soft tissue discrimination
- Accurate, reliable HU calibration
- High spatial resolution and MTF

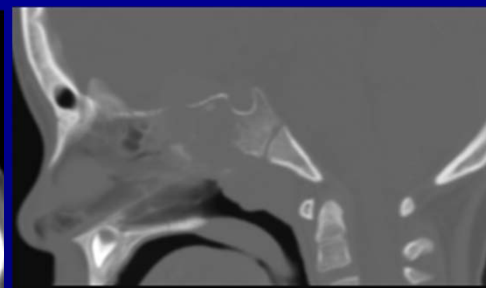
4 year old with 2 week history of headaches, abdominal pain, anorexia and vomiting. Recent antibiotics for sinusitis.



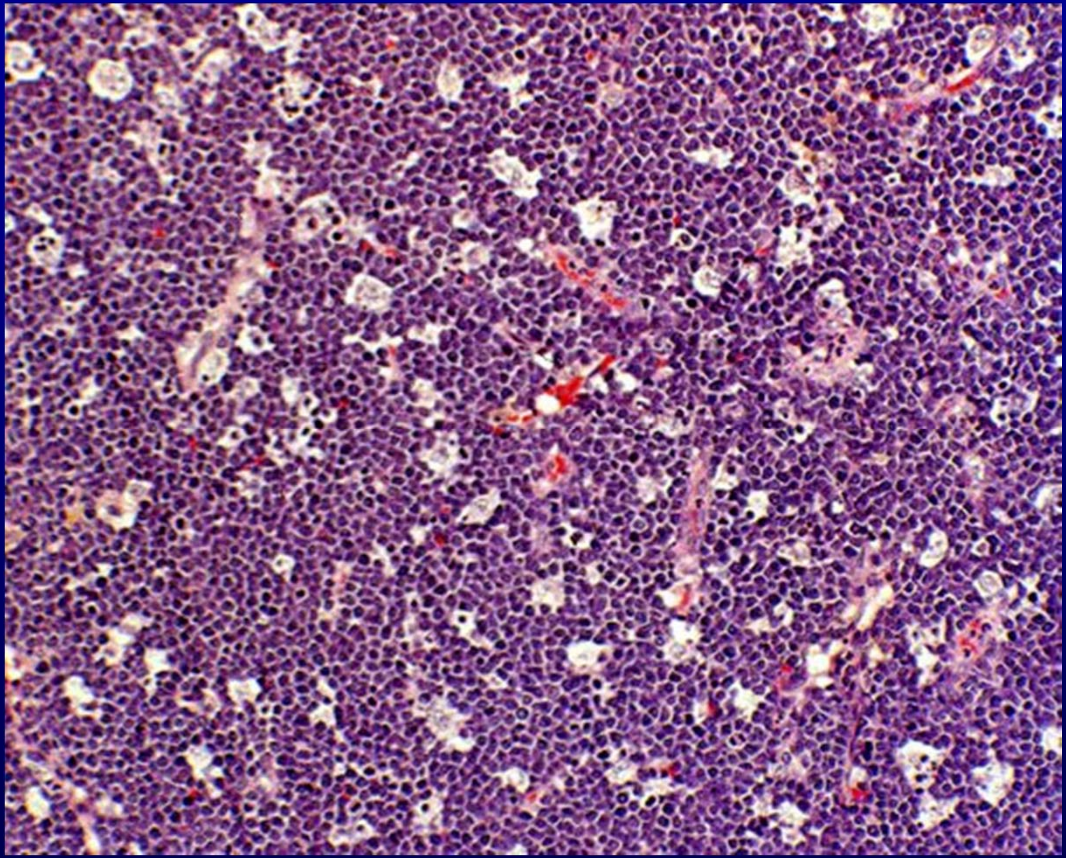
Artifact or Pathology?

Imaging 1 Week Later

CT w/ Contrast



Pathology: Burkitt Lymphoma



B-cell lymphoma

Beam Hardening

- Effective beam energy increases.
- Beam "hardens" as it penetrates.
- Higher E => lower μ.
- "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)

Series Auto Transf		OFF
Mode		Helical
Time		0.7
DMPR		ON
Thickness		1.25
Pitch		0.531:1
Speed		10.62
Interval		0.625
Rotation Time		0.7
Gantry Tilt		0
SFOV		Head
KV		120
mA		250
DFOV		22
ALG		Standard

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

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

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" kernals
  - Filters, e.g. metal streak reduction
- Optimize readout
  - Coronal Reformats
  - Optimal PACS display
  - Appropriate window/level settings

Michael Lev, MGH

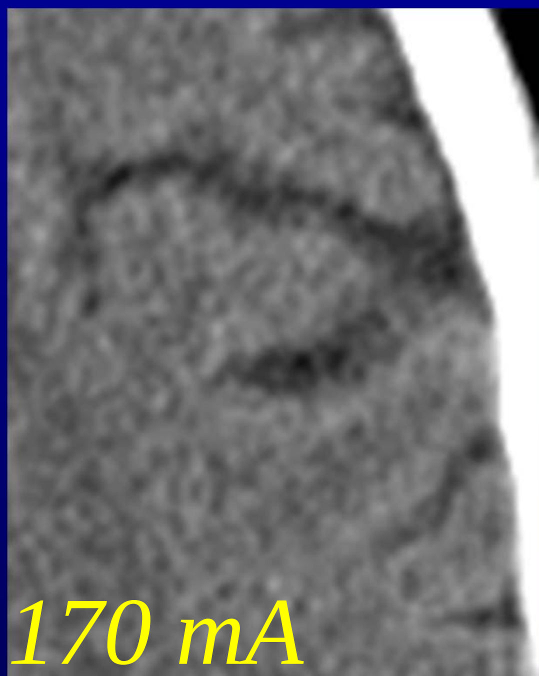
Optimizing Dose: Basic Principles

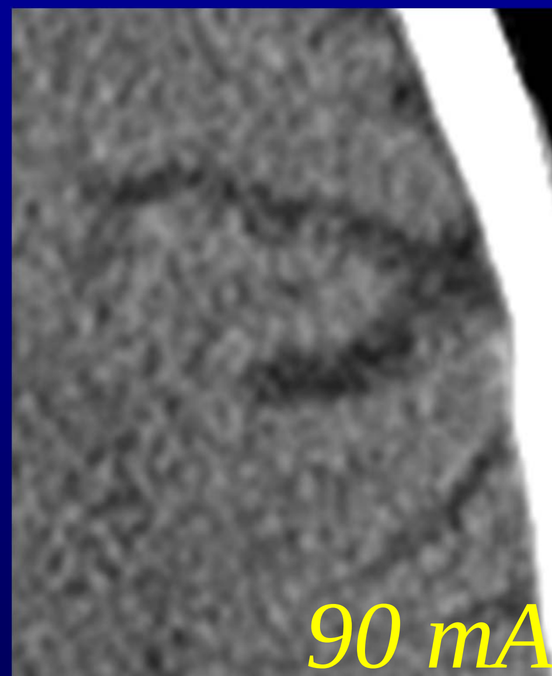
- Lowest possible mAs is proportional to:
  - Degree of intrinsic tissue contrast
  - Acceptable level of image noise
  - Noise ~ 1 / SQRT (mAs)
- Tailor the protocol to the clinical question
  - *E.g.*: 30 mAs for sinus CT, FESS planning

    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)

Mullins, Lev, et al. "Comparison of image quality between conventional and low dose NCCT." AJNR, Apr 2004.

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

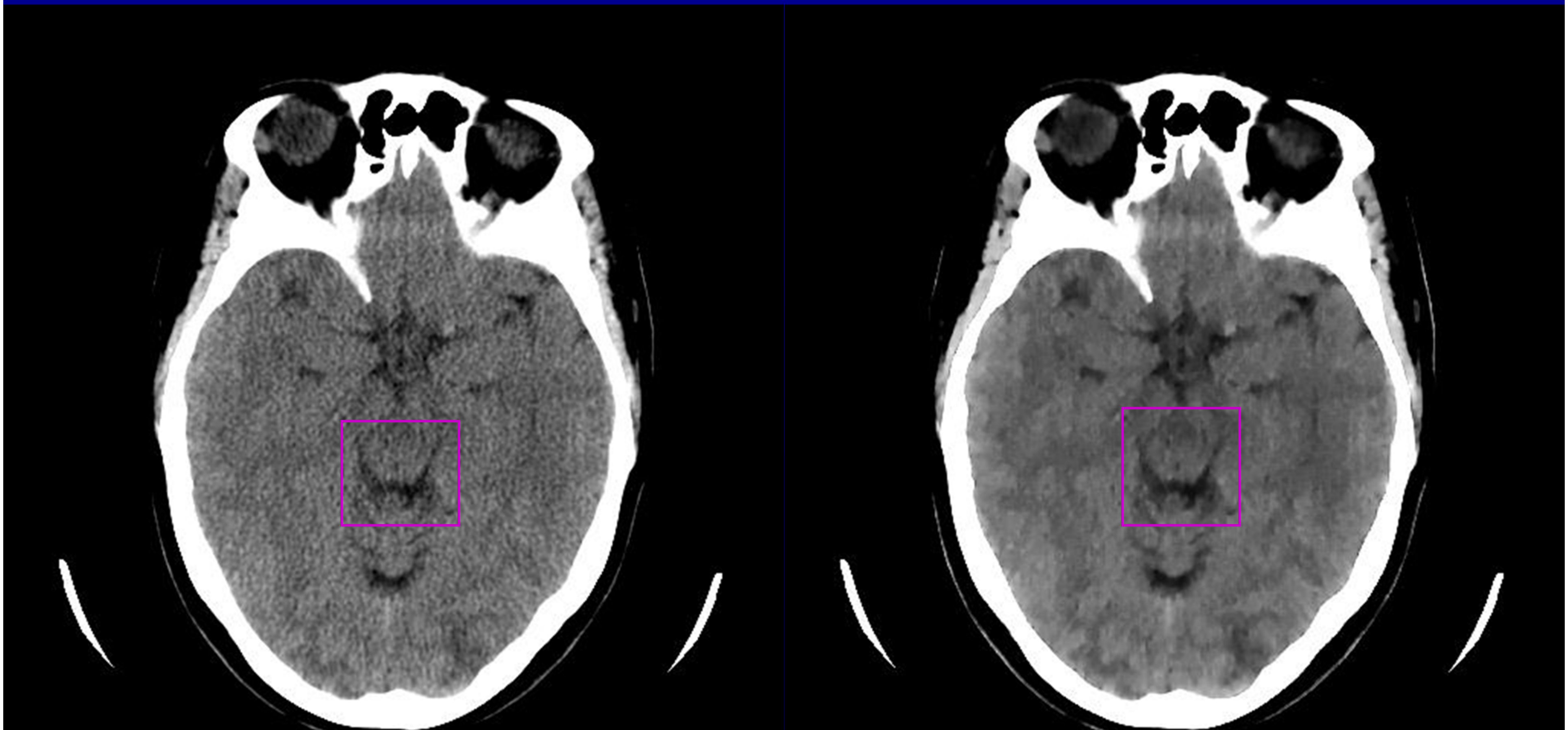
- Lower kV
  - Increased photoelectric effect
  - Higher HU iodine
- Avoid rescanning same region
  - E.g., head and temporal bone, face and sinuses (*? billing*)
- Maximize quality parameters
  - Decrease motion artifact: speed, sedation
  - Remove extraneous hardware
  - Optimize contrast bolus; right 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

HEAD

		kv	mA	Noise (ADM)	ASIR	Rot speed	Pitch	CTDIvol	DLP
Head I-&I+	Current	120	200		30%	0.7	0.531:1	49.7	932.25
	previous	120	250		0%	0.7	0.516:1	66.51	1270.34
CTA (Head)	Current	120	235		30%	0.5	0.531:1	41.18	733.57
	previous	120	350		0%	0.5	0.516:1	59.62	1170.17
CTA (H&N)	Current	120	min 350 max 600	13	30%	0.5	0.984:1	29.89	1333.86
	previous	120	min 350 max 600	10	0%	0.5	0.516:1	57.06	2518.04

SPINE

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

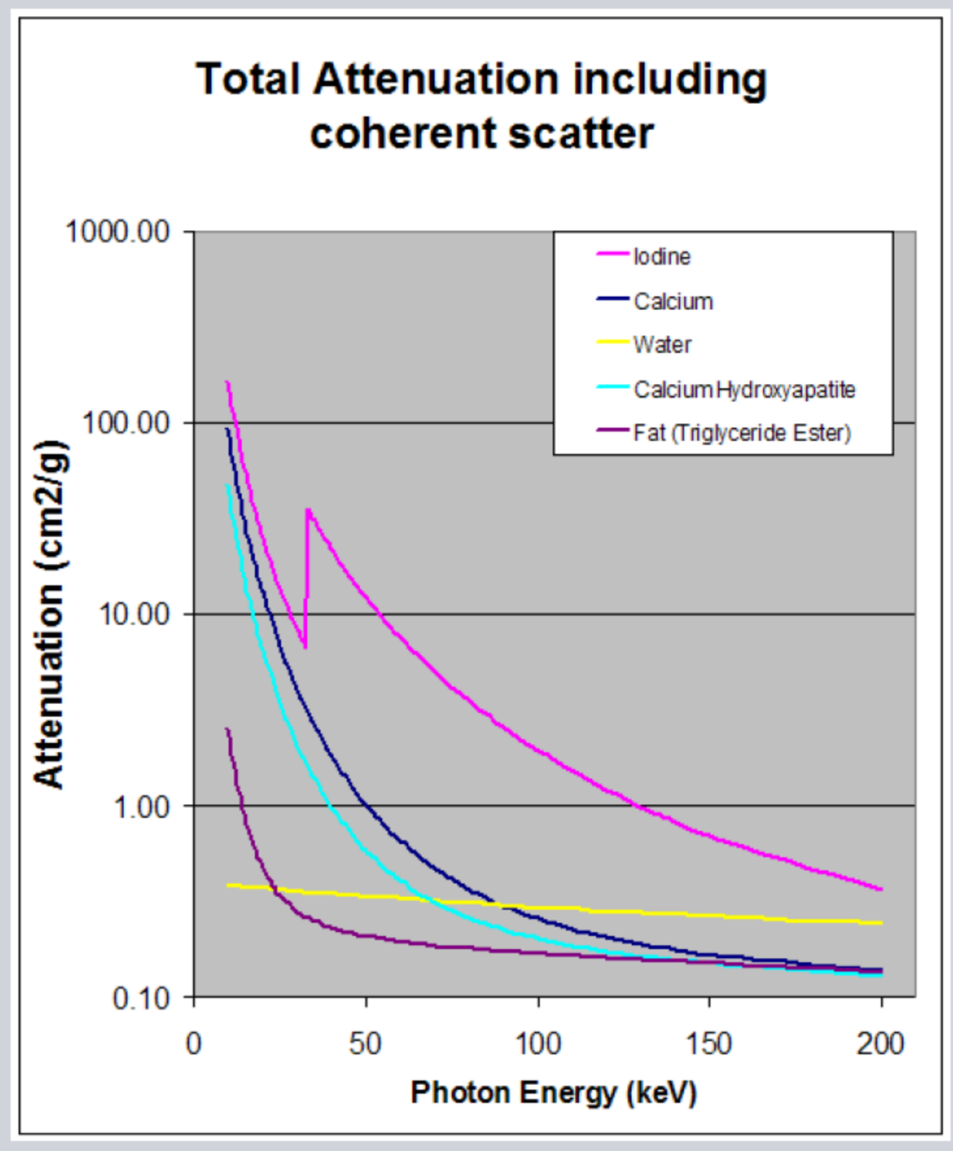
VCT	kv	mAs (ADM)	ADM Noise	ASIR	Pitch	Rotate speed	CTDIvol	DLP	Thickness
C spine	140	Min 100 Max 715	20	0%	0.561:1	0.5	42.04	1056.46	0.6
T/L spine	140	Min 100 Max 715	20	0%	0.561:1	0.5	77.92	1860.57	0.6

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

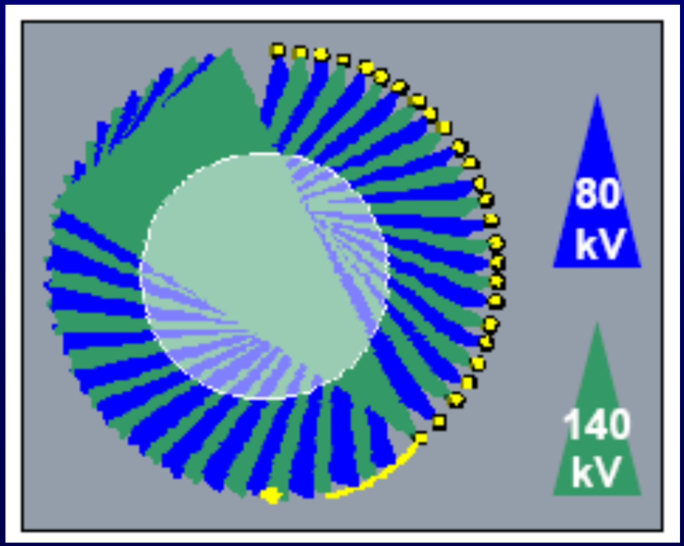
- Total attenuation decreases with increasing energy
- Decrease is characteristic for each material
- Depends on photon energy and material density
- X-ray absorption depends on the inner electron shells
  - DECT is sensitive to atomic number and density
  - DECT is not sensitive to chemical binding



C. Leidecker, Siemens

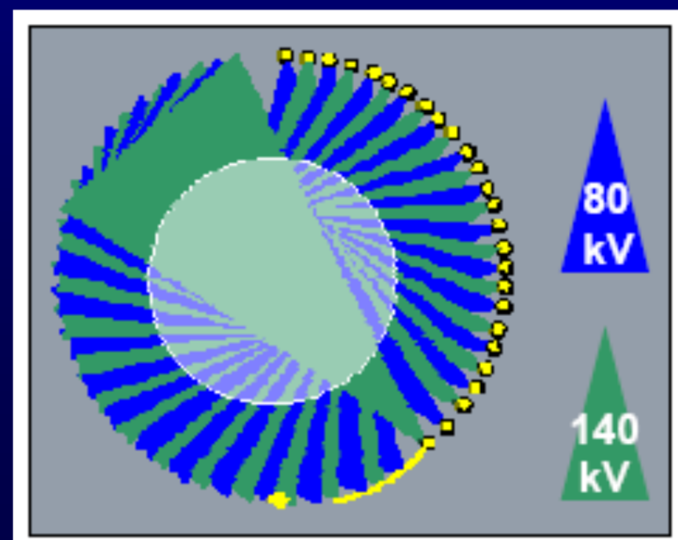
Dual Energy Systems

Siemens: Dual Source CT (Definition)	General Electric: Discovery Gemstone (HD-750)
• Two X-ray sources, two detectors, simultaneous acquisition • Operate one source at 80kV and the other at 140kV	• 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)	General Electric: Discovery Gemstone (HD-750)
• Simultaneous acquisition • Optimized tube current • Projections: 90 deg apart • One detector smaller than other	• Projections close to each other in time => separation in projection domain • Tube current constant (i.e., not optimized for each kV).



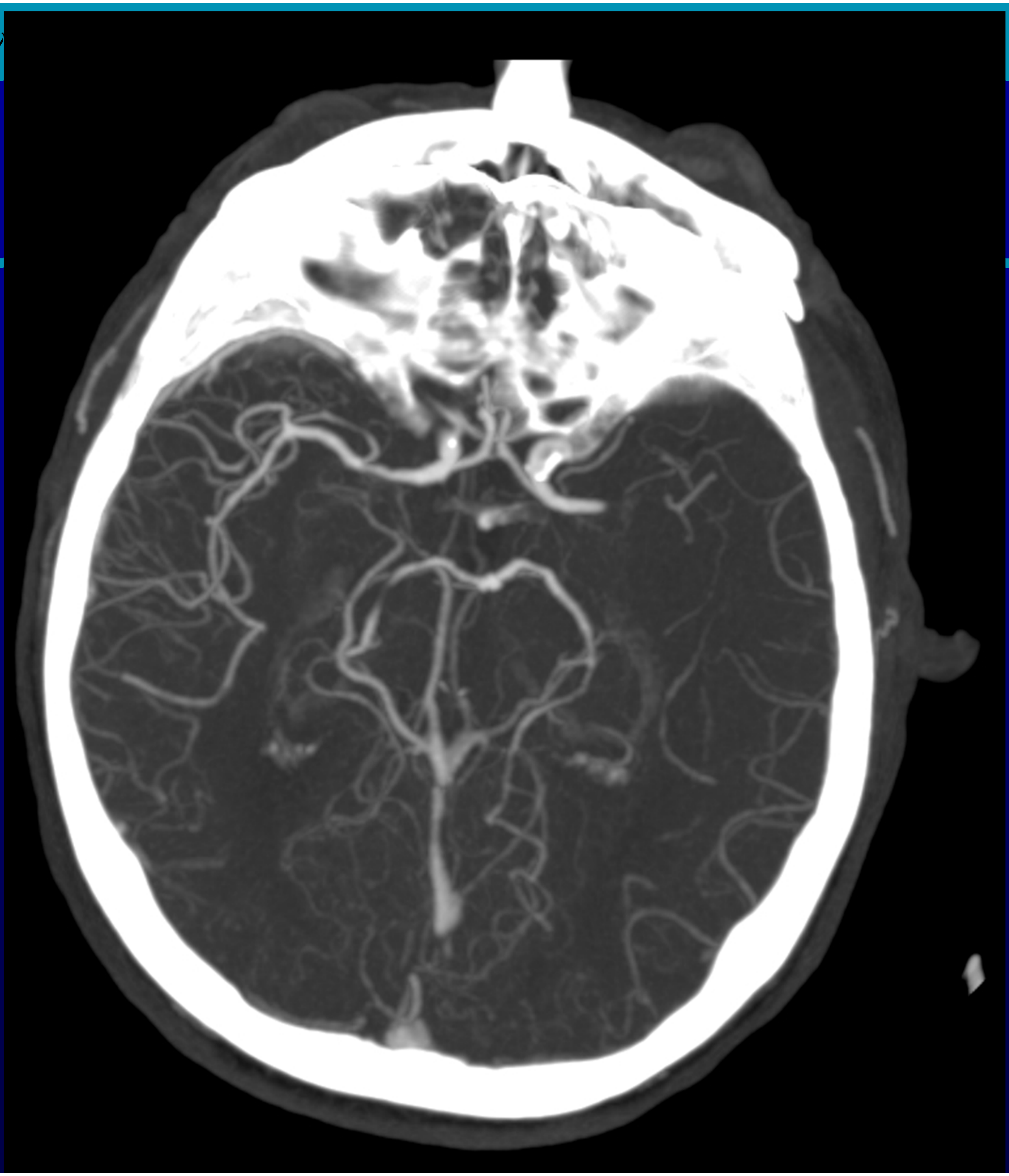
Clinical Case

- 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

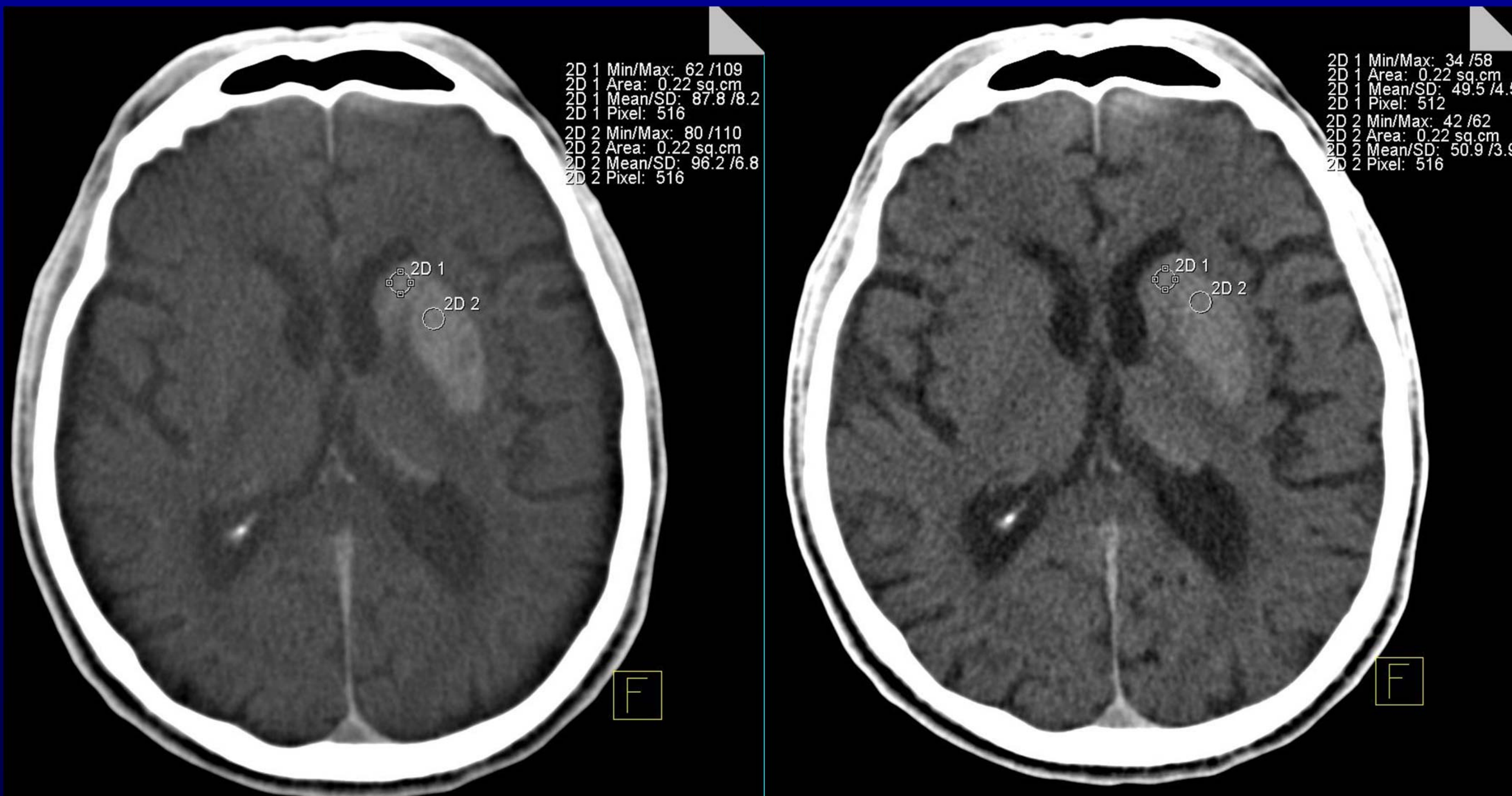
Technology



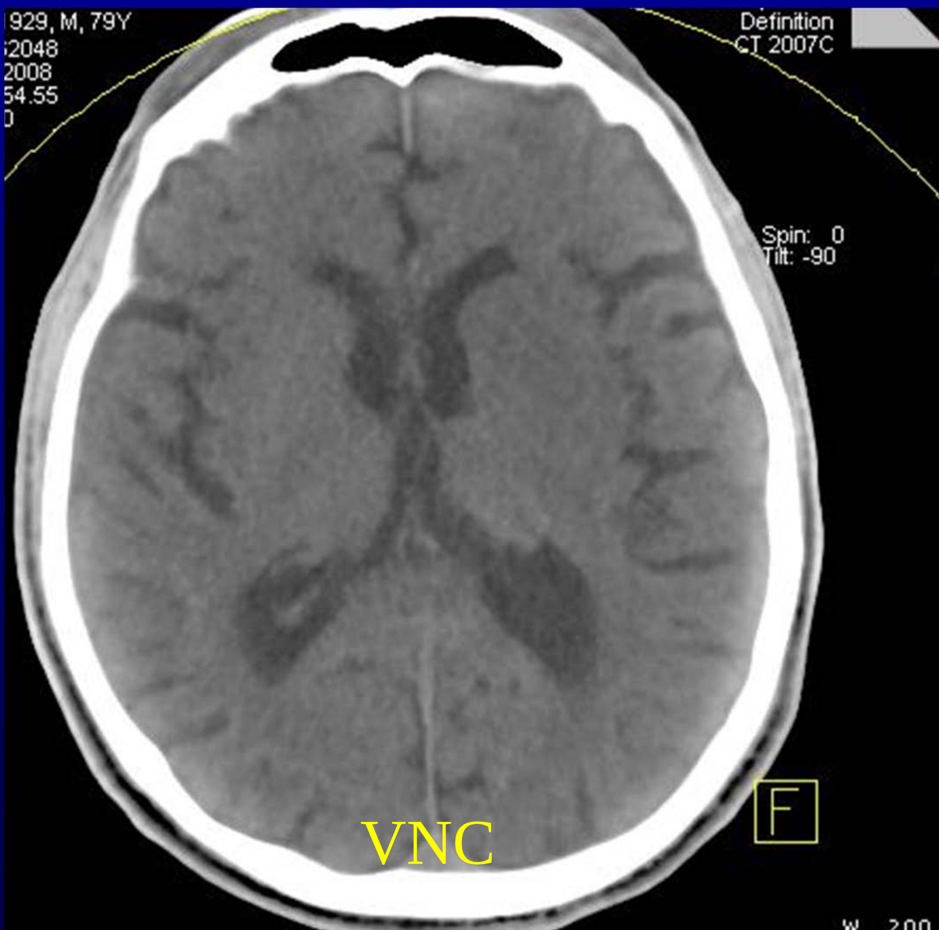
Cath Lab: Recanalization

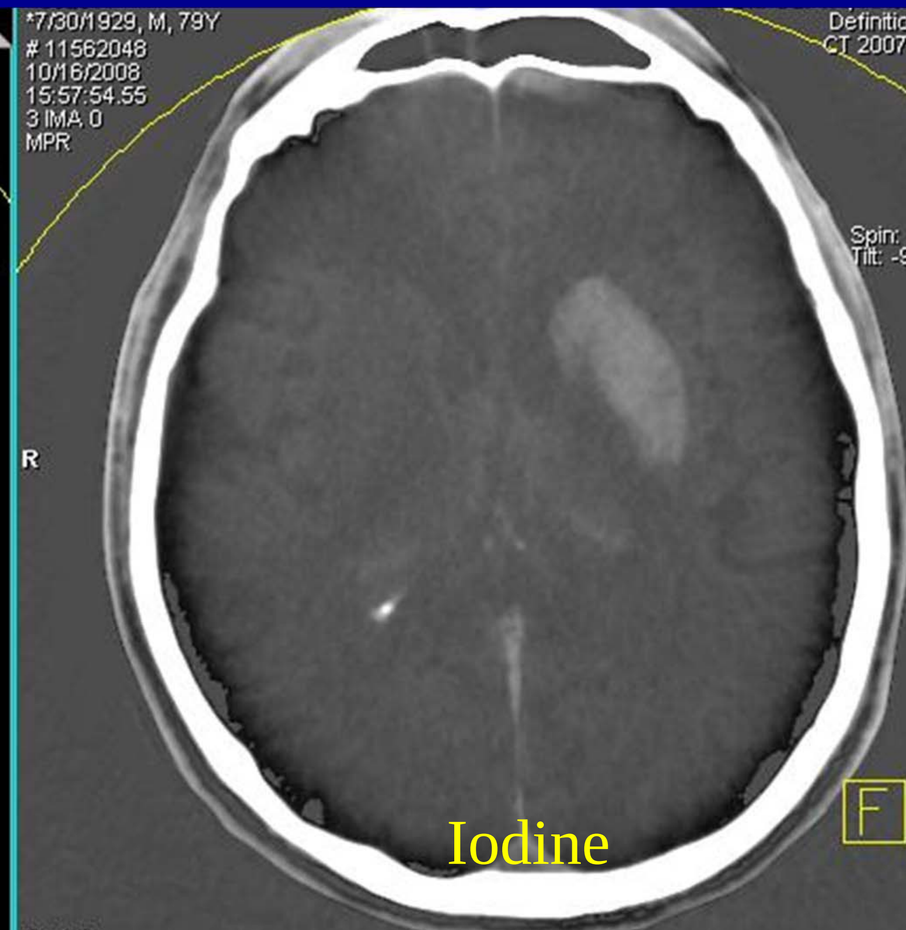
80 kV

Post-op: 80kV and 140 kV Images

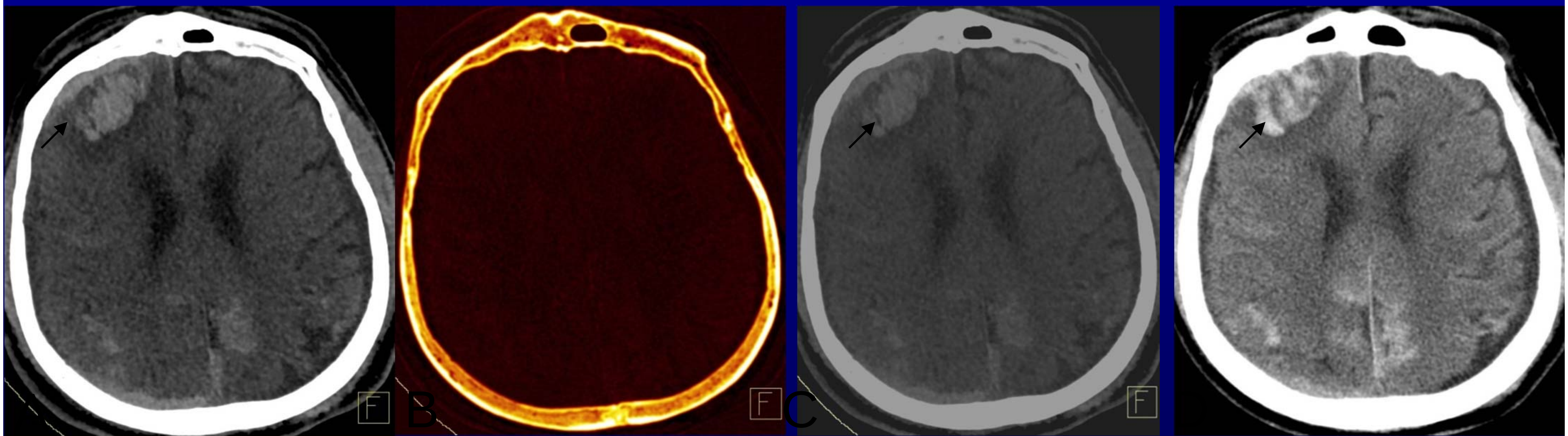


VNC and Iodine Overlay Images





Intra-parenchymal Hemorrhage



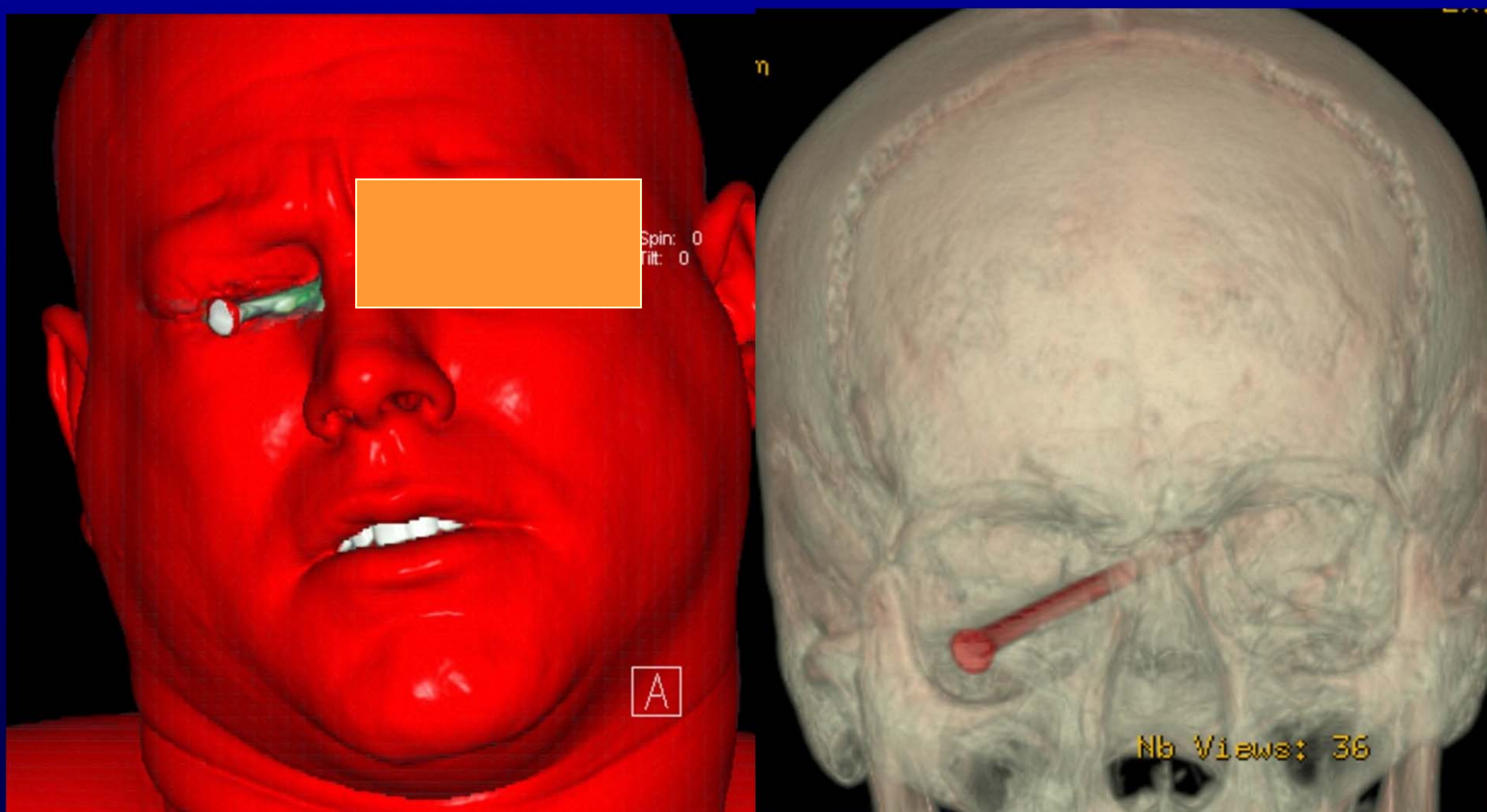
Single Energy	Iodine Overlay	Virtual Non-contrast	Follow-up Image

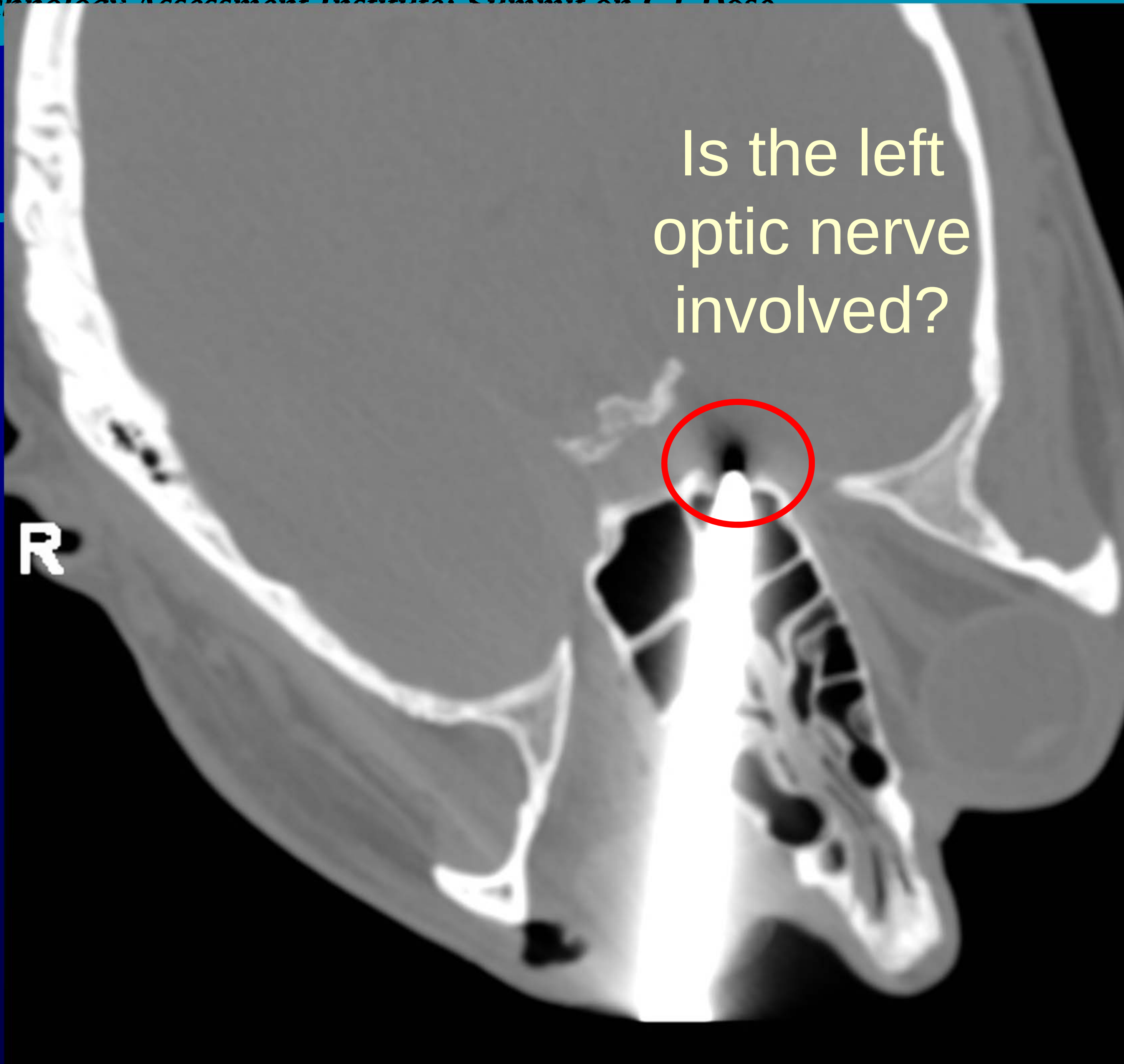
Virtual Monochromatic Images

- Are they clinically useful?

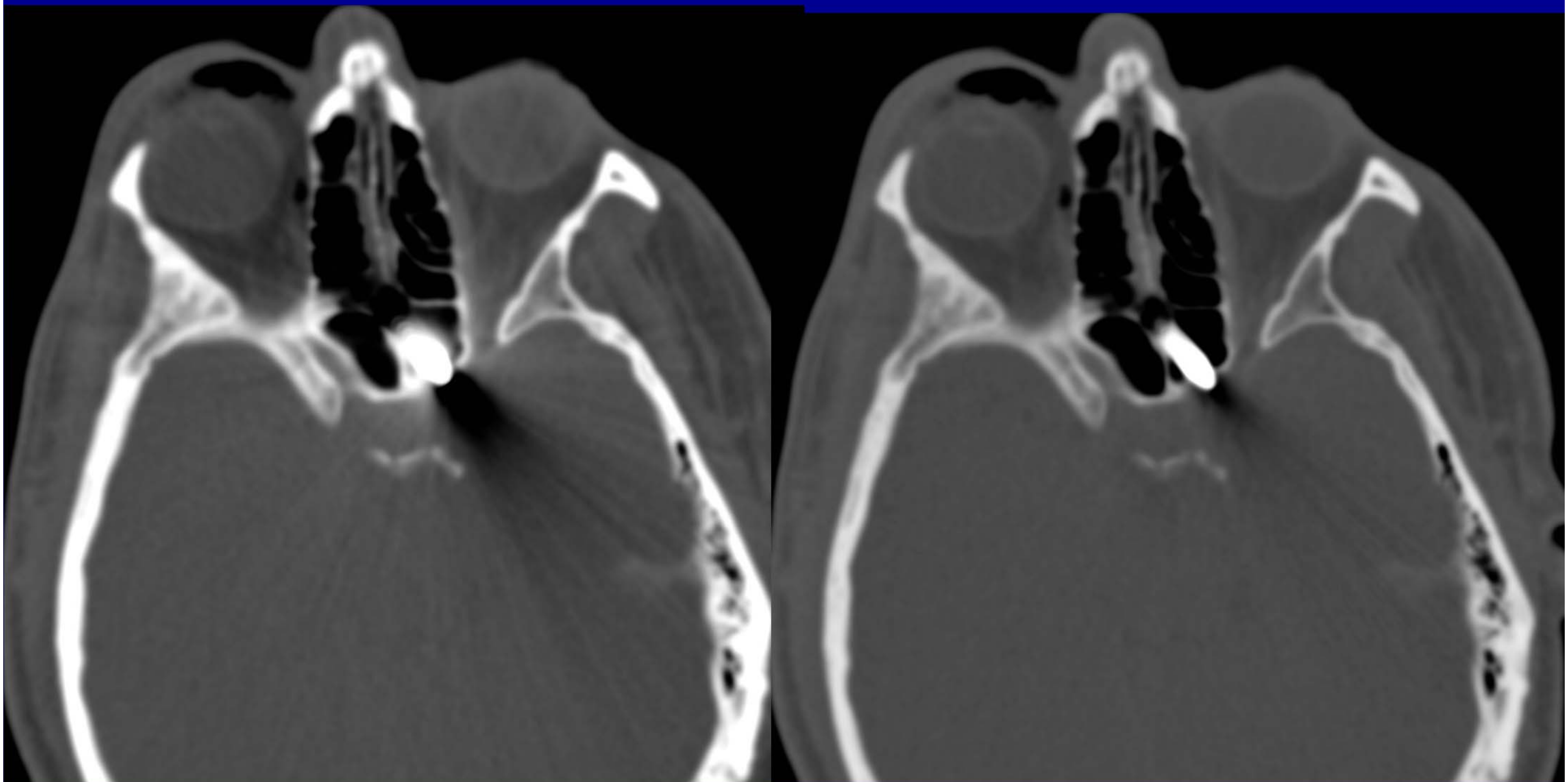
27 year-old male presents to ER complaining of sudden onset of severe right sided eye pain while using a weed whacker

27 year-old after a weed whacker accident




Is the left
optic nerve
involved?
R

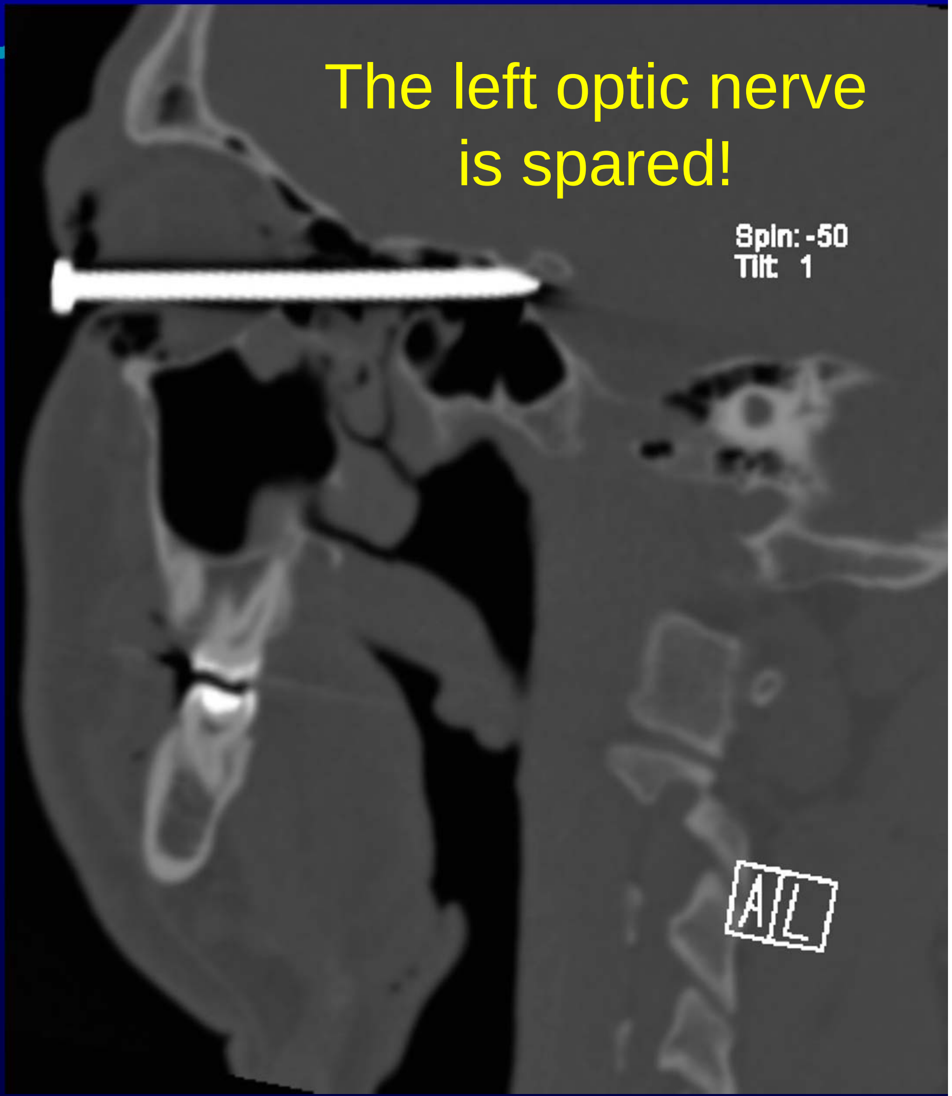
Metal artifacts, identical W/L setting



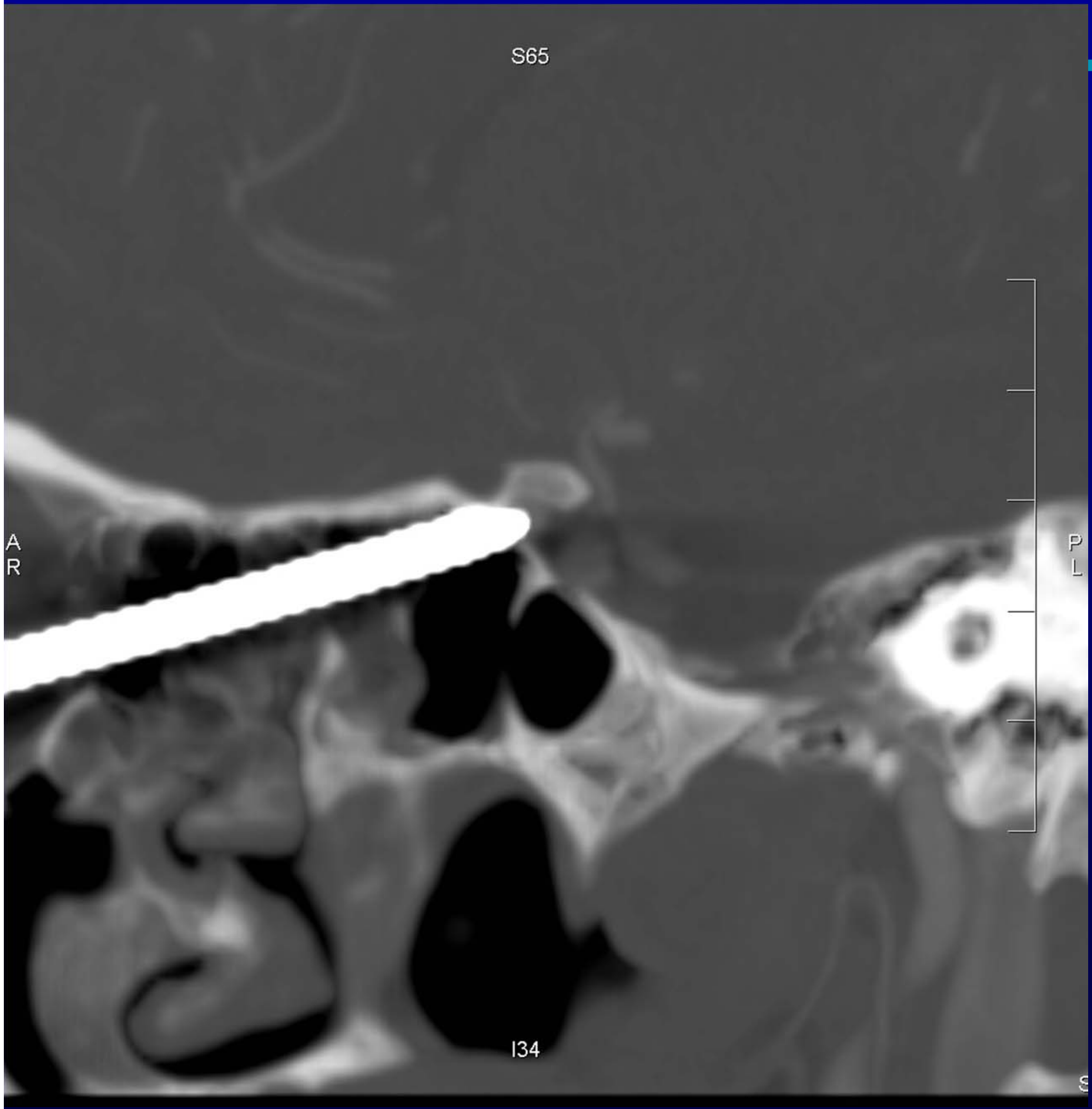
80 kV 140 kV

4955492

Monochromatic 190kV Images

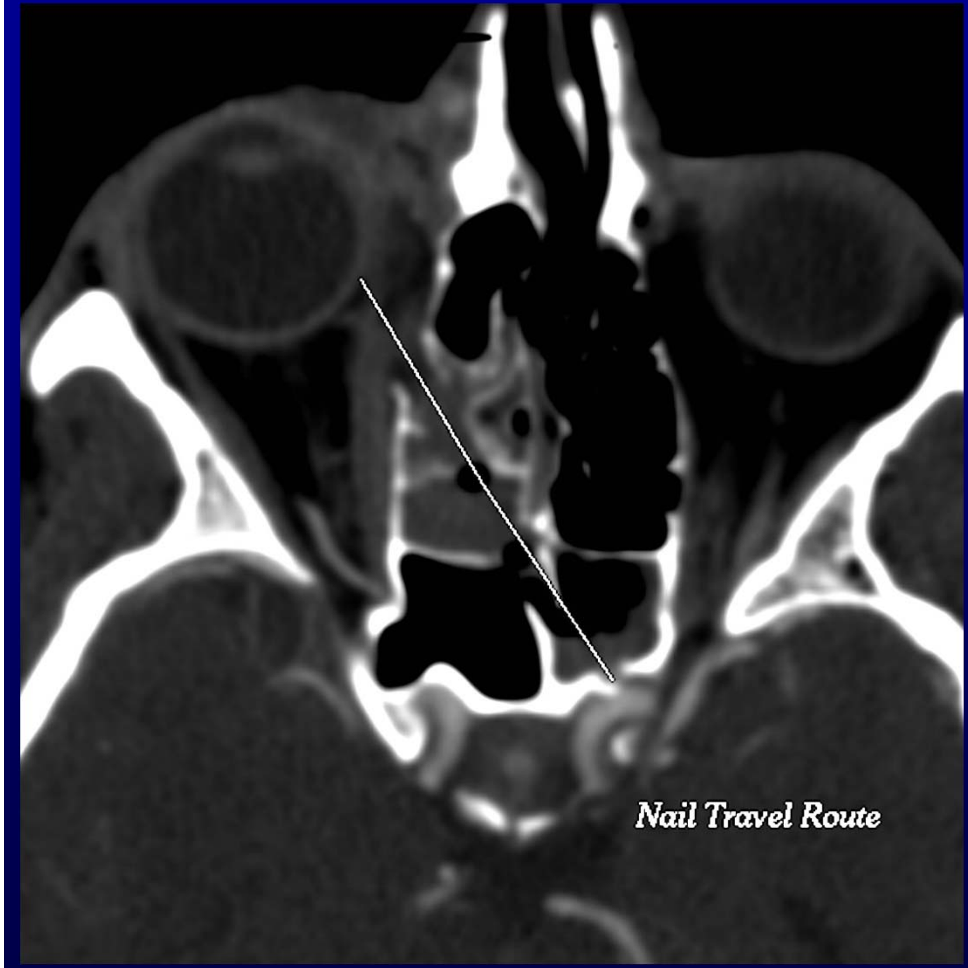


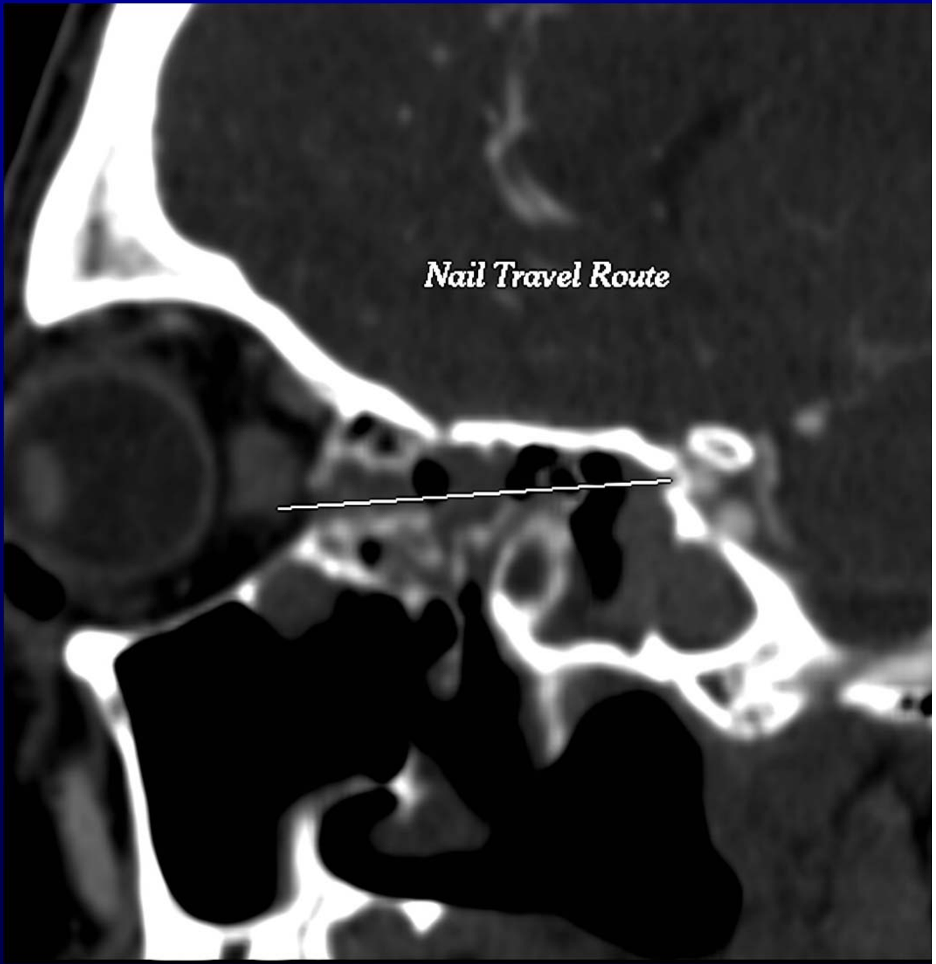
Pre-Op CTA



- 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