3RD CT DOSE SUMMIT:
STRATEGIES FOR CT SCAN PARAMETER OPTIMIZATION
MARCH 15 - 16, 2013 • PHOENIX, ARIZONA

SPECIFIC PRINCIPLES FOR DOSE REDUCTION IN HEAD CT IMAGING

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OUTLINE

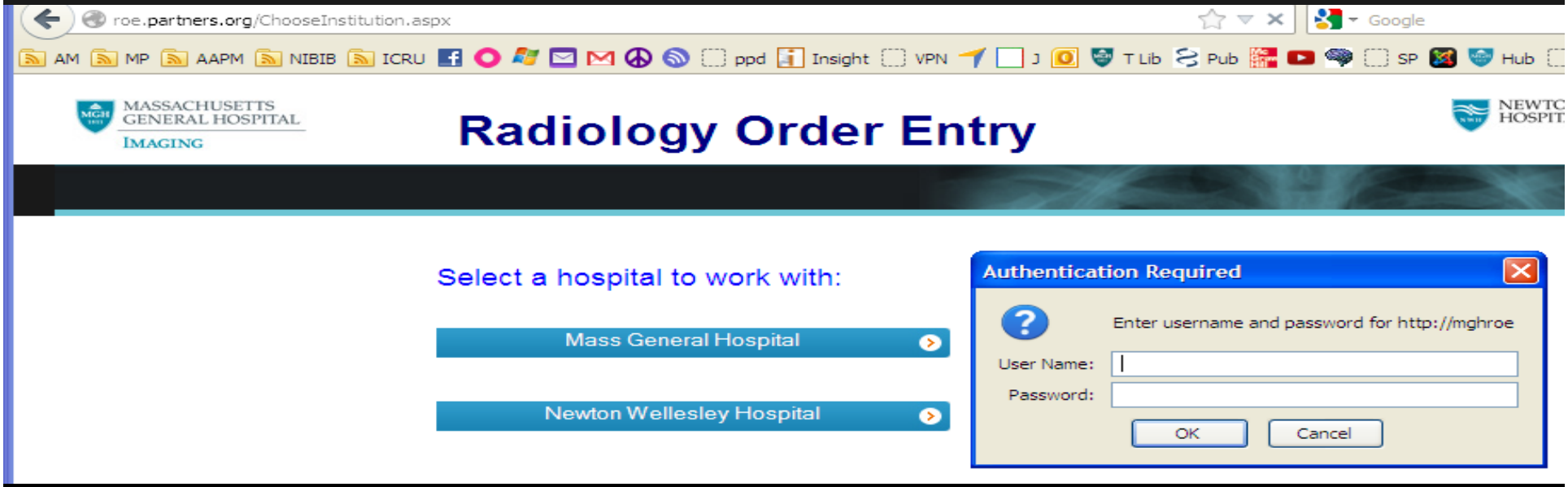
- 1st Presentation:
  - Dose optimization strategies
  - Routine Head CT protocols
- 2nd Presentation:
  - What we need to see?
  - Effect of parameters and image review
  - Some newer tricks using Dual Energy CT

STRATEGY: MAKE SURE THAT EACH SCAN IS JUSTIFIED

MAKE SURE EACH SCAN IS JUSTIFIED

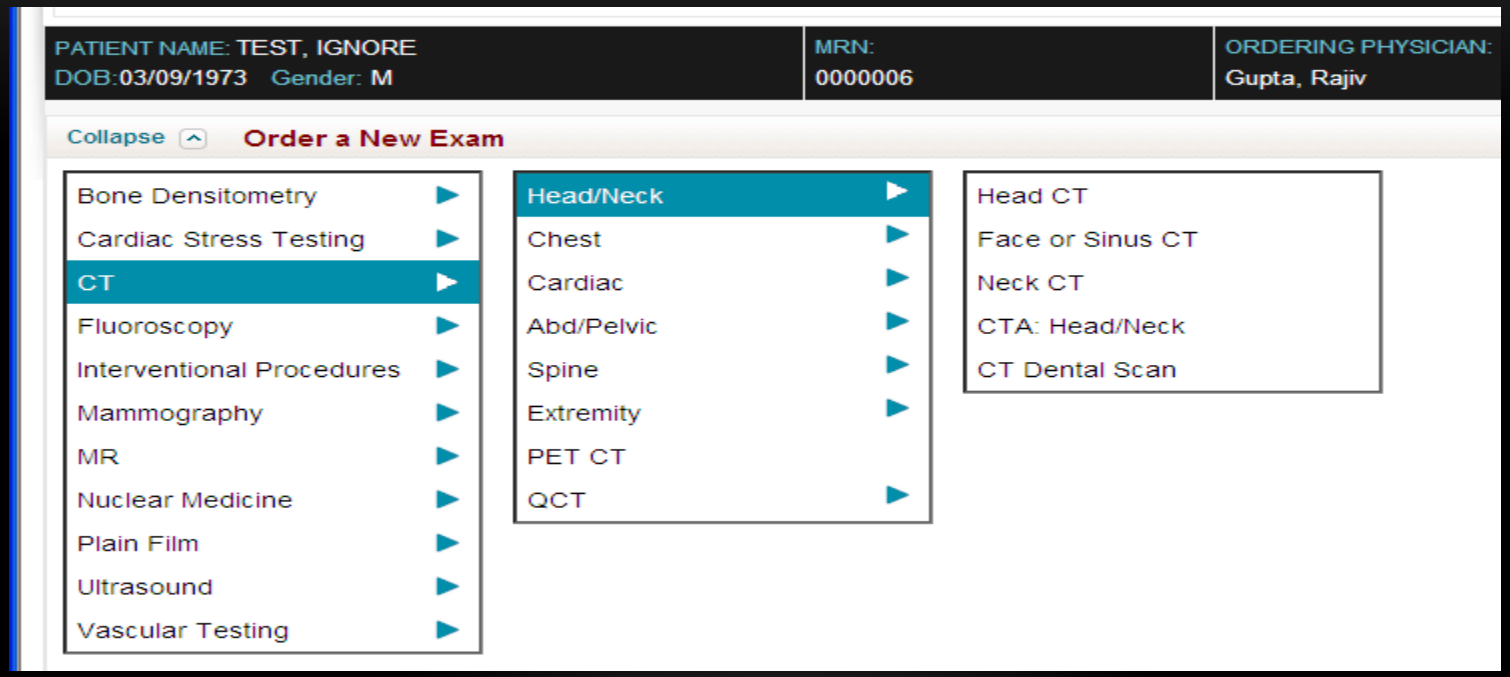
- Even a low-dose CT is too much dose when inappropriately ordered
- Check with physician if in doubt; Triage when appropriate
- About 1/3rd of CT are inappropriate!
  - Brenner, NEJM 2008

ROE



Courtesy of Sarabjeet Singh, MD

ROE: SELECT A MODALITY AND A BODY PART



Courtesy of Sarabjeet Singh, MD

ROE: SELECT A SPECIFIC EXAM AND CONTRAST USE

To order a CTA exam please select it from CT drop-down menu.

Exam Requested

Exam Request / Protocol	Includes the following examinations
◉ CT Head	CT Head or Brain
○ CT Head & Neck	CT Head or Brain and CT Neck
○ Pediatric Head for Craniosynostosis	CT Head or Brain without contrast and 3D reconstructions
○ Pediatric Head for Trauma	CT Head or Brain without contrast
○ CT Base of Skull	CT Base of Skull

Protocol

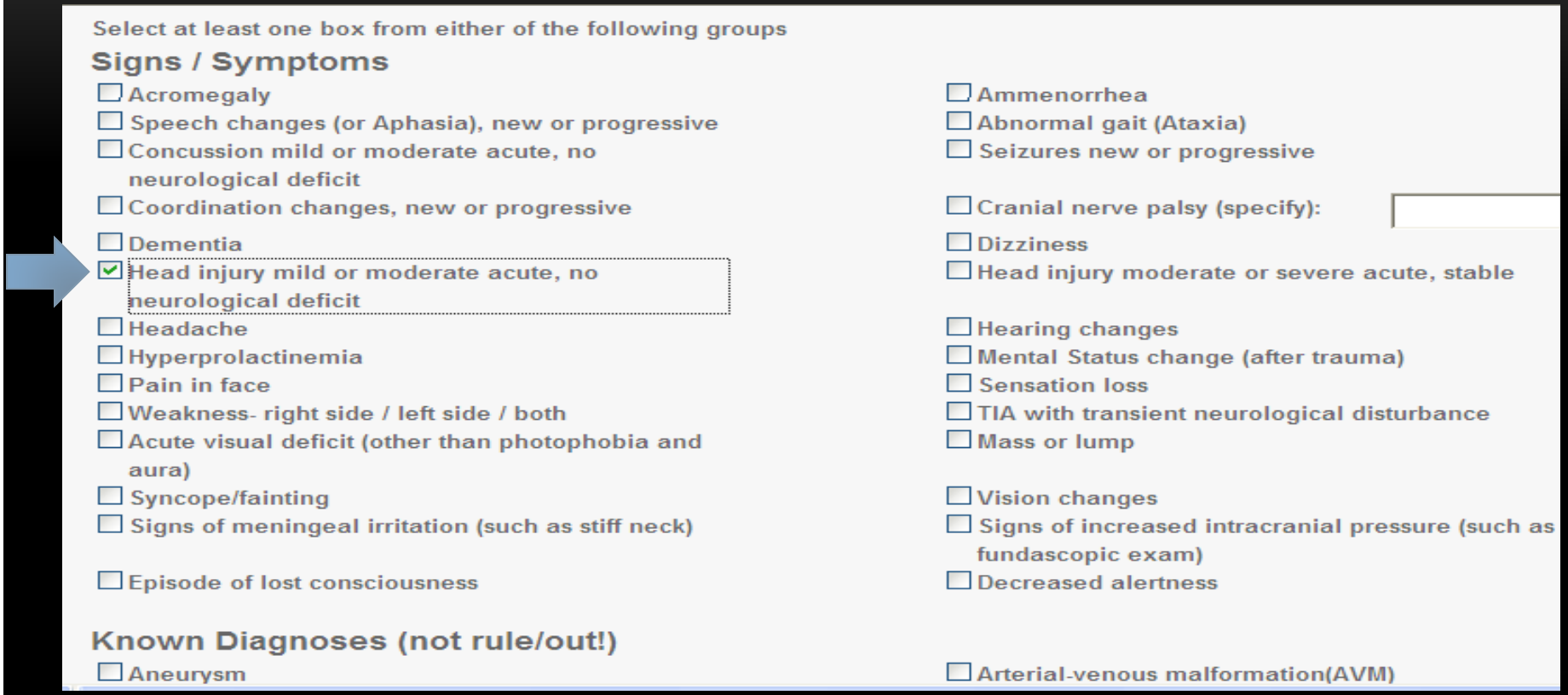
☐ 3D

Intravenous Contrast

◉ Contrast use at Discretion of Radiologist
○ Do not use contrast
○ Use contrast

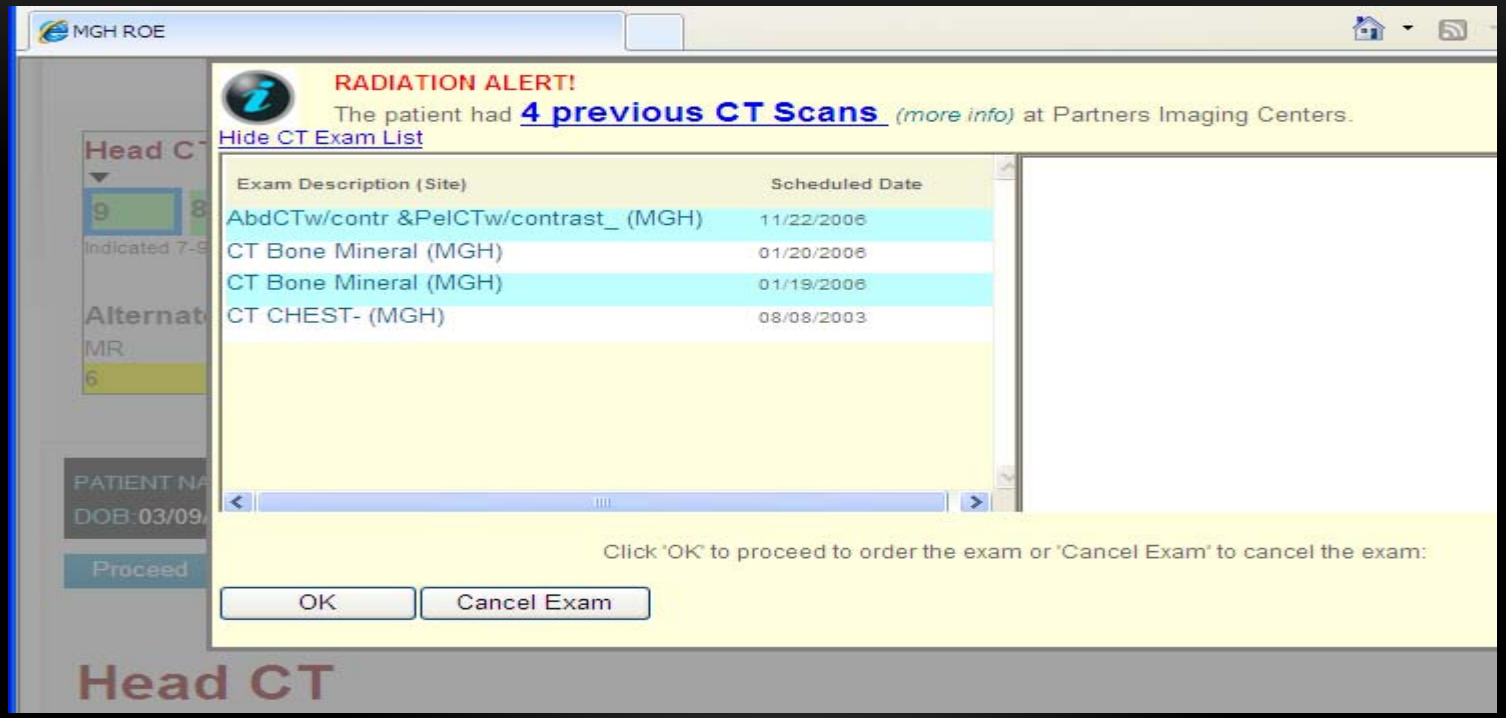
Courtesy of Sarabjeet Singh, MD

ROE: ENTER SIGNS AND SYMPTOMS



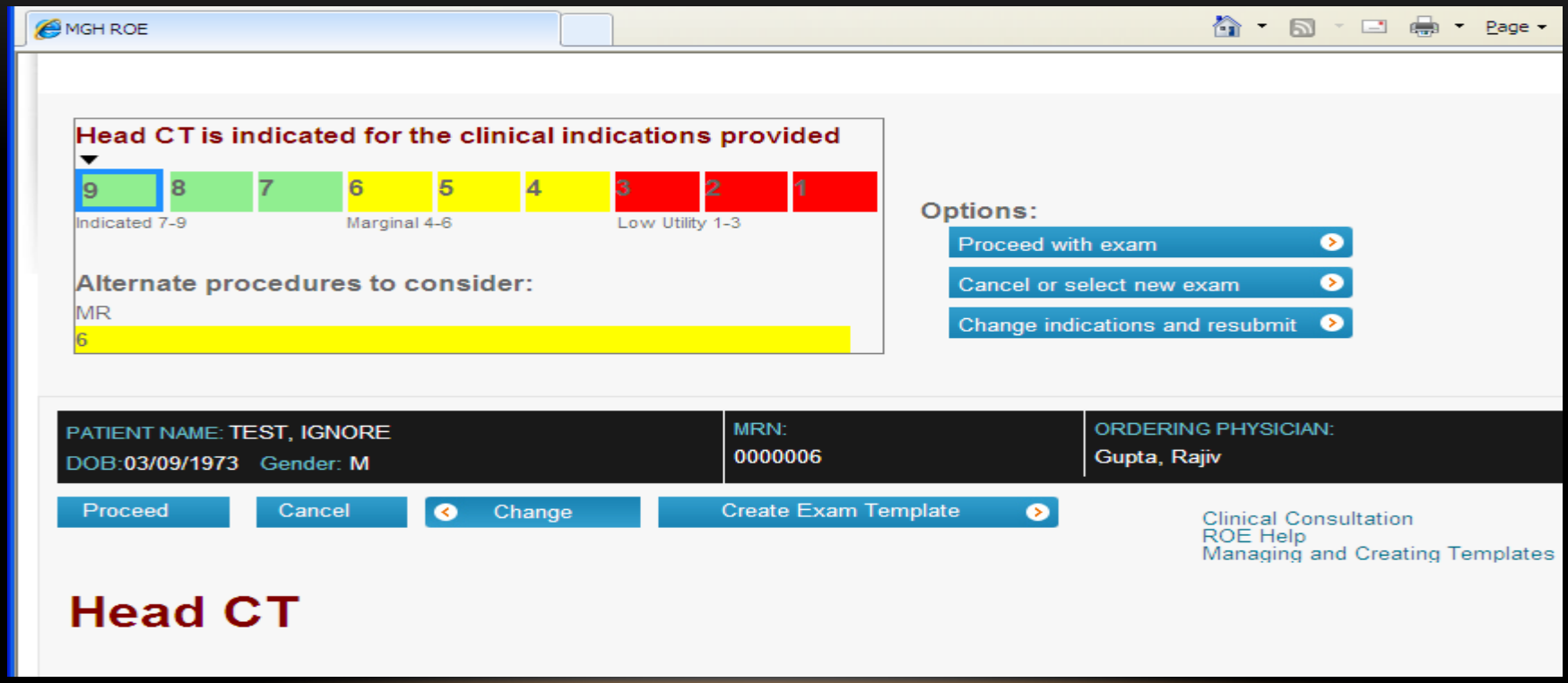
Courtesy of Sarabjeet Singh, MD

ROE: SHOWS PREVIOUS EXAMS



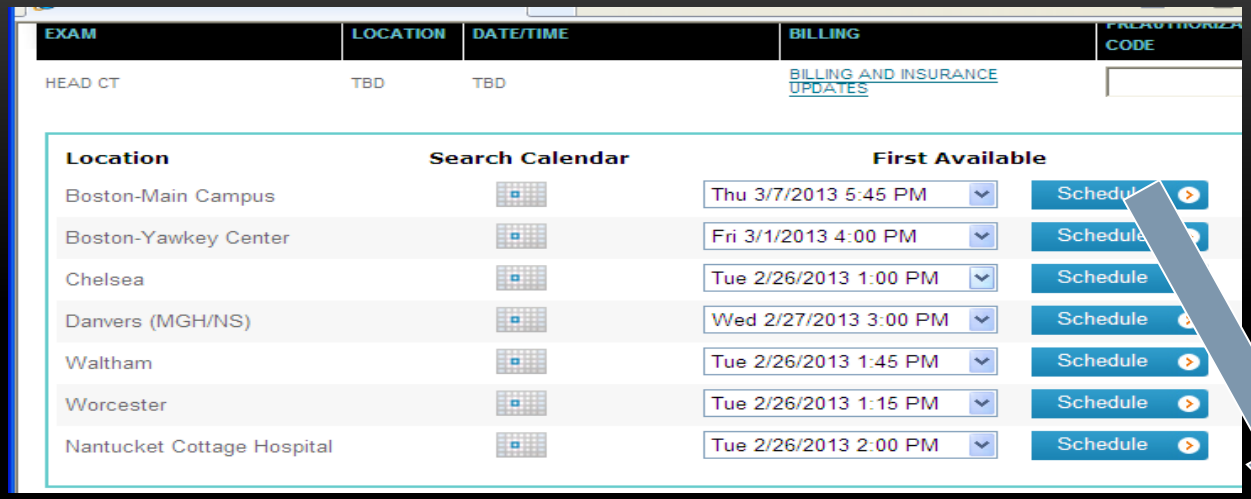
Courtesy of Sarabjeet Singh, MD

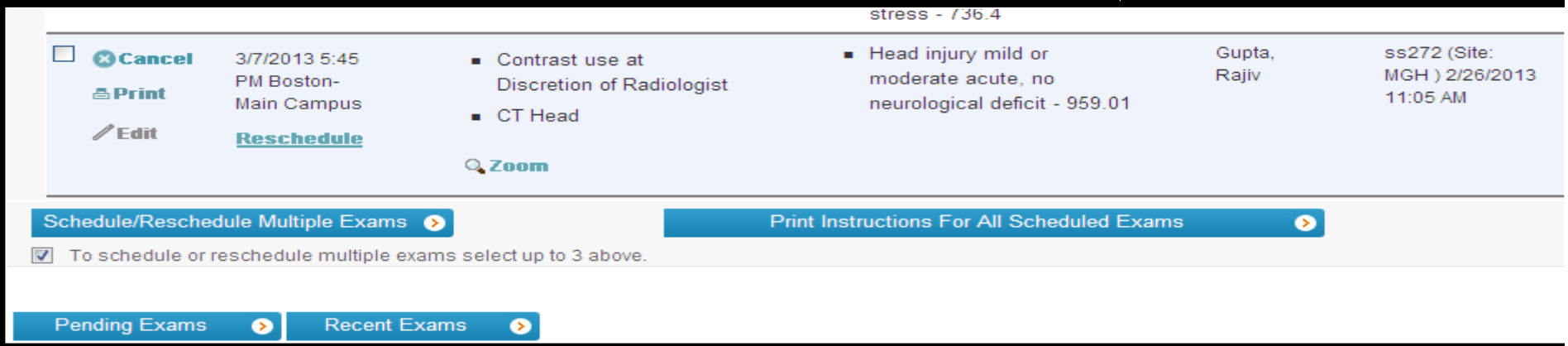
ROE: EVIDENCES-BASED APPROPRIATENESS



Courtesy of Sarabjeet Singh, MD

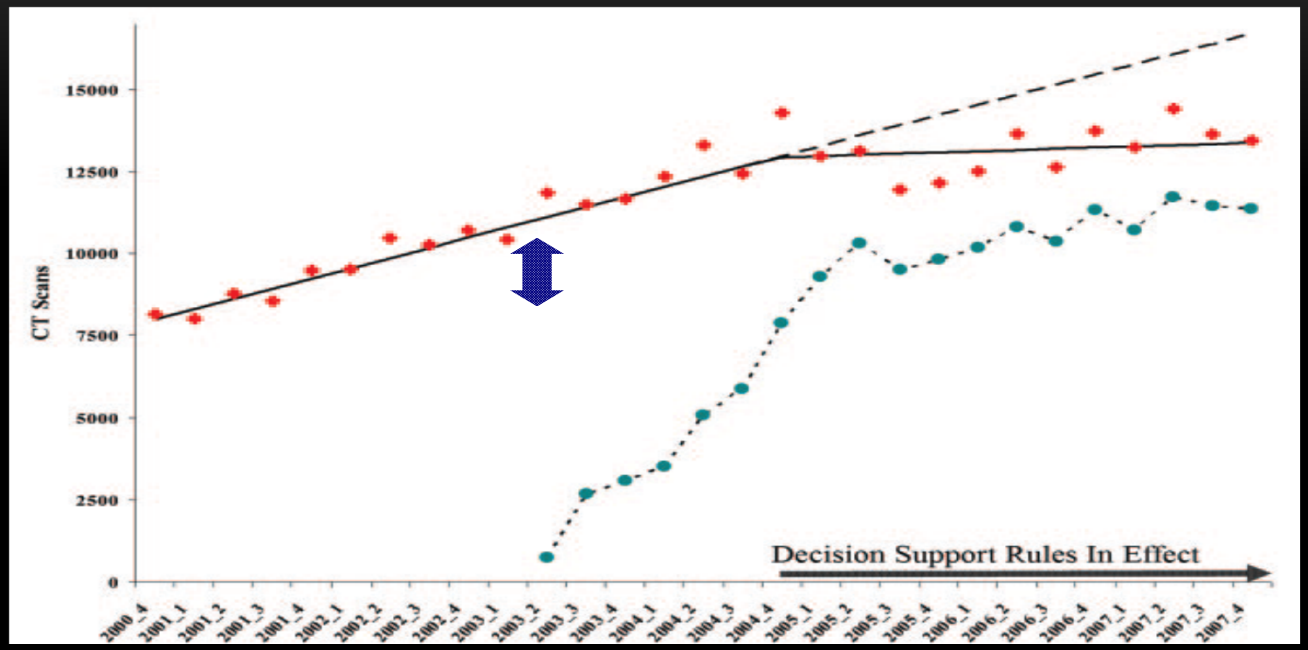
Select Site and Schedule Exam





Courtesy of Sarabjeet Singh, MD

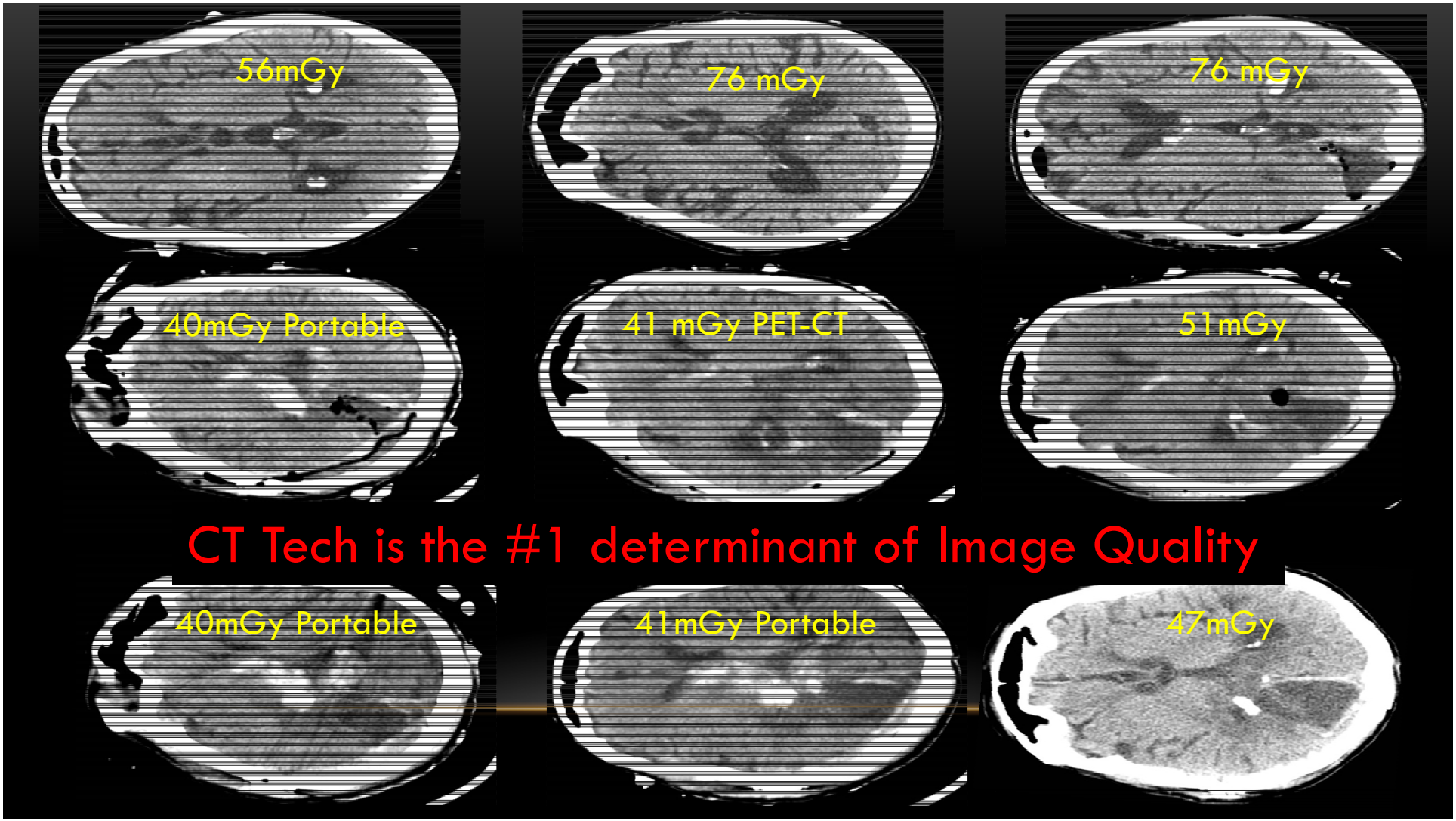
DECISION SUPPORT: EFFECT ON VOLUME



Sistrom et al. Radiology 2009

- Appropriateness for CT is not optional!
- Decision support and practice guidelines help.

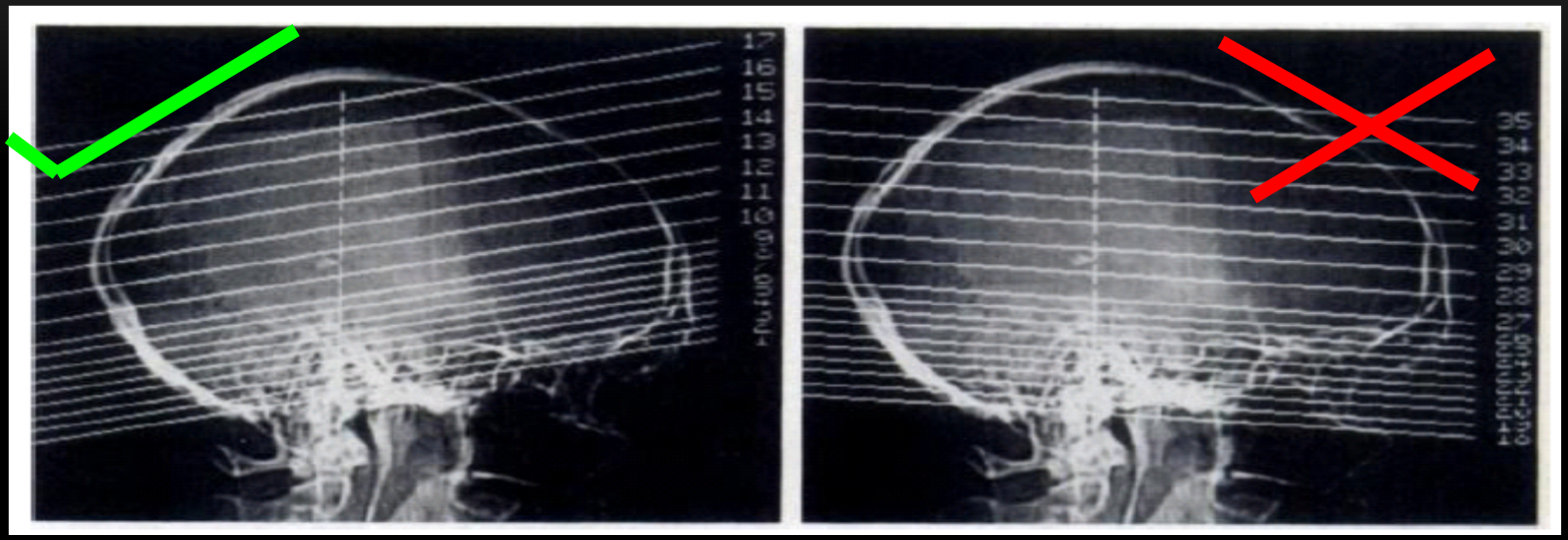
STRATEGY: ACQUIRE EACH SCAN WITH CARE AND LOVE


56mGy
76 mGy
76 mGy
40mGy Portable
41 mGy PET-CT
51mGy
CT Tech is the #1 determinant of Image Quality
40mGy Portable
41mGy Portable
47mGy

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

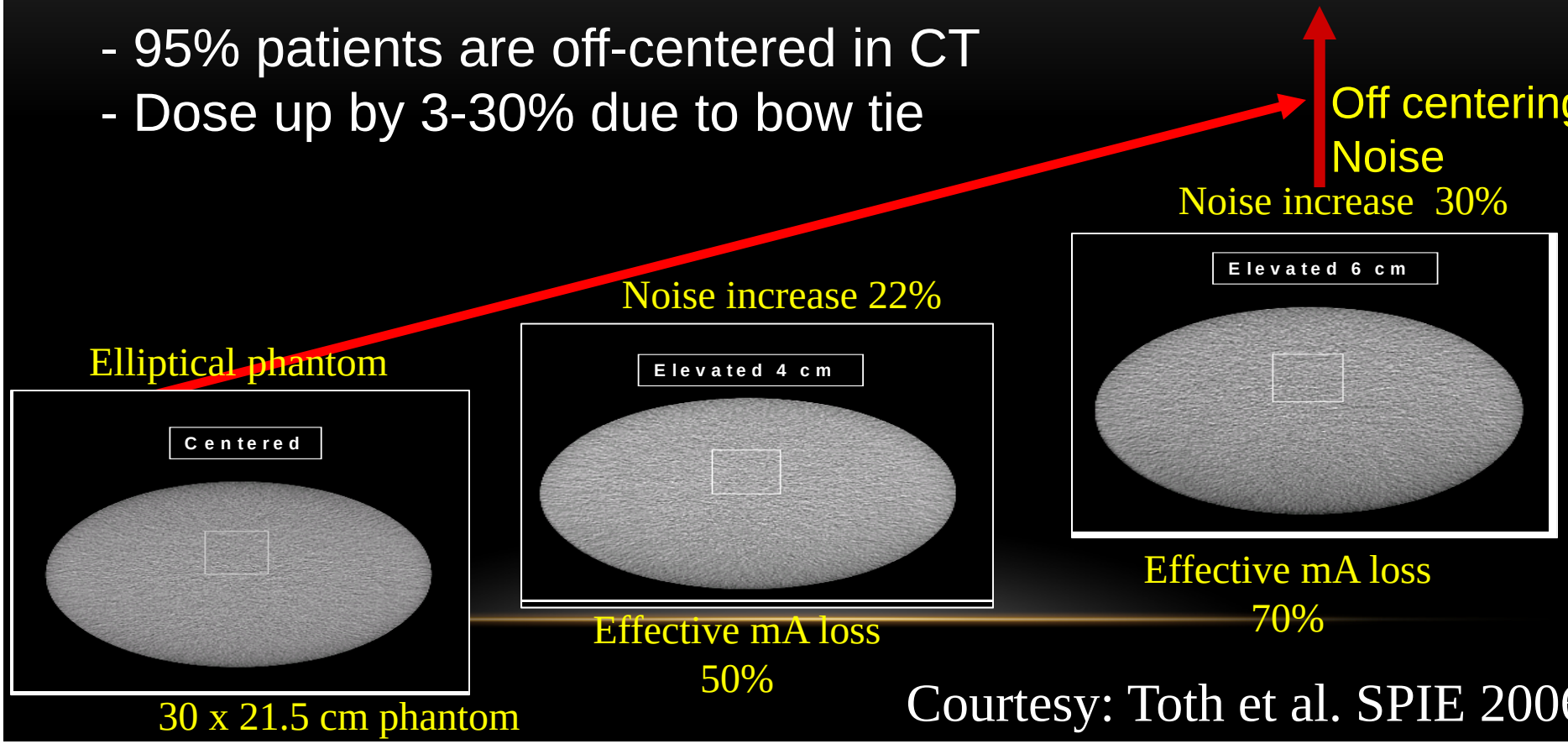
GANTRY ANGULATION FOR HEAD CT



- 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



Courtesy: Toth et al. SPIE 2006

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

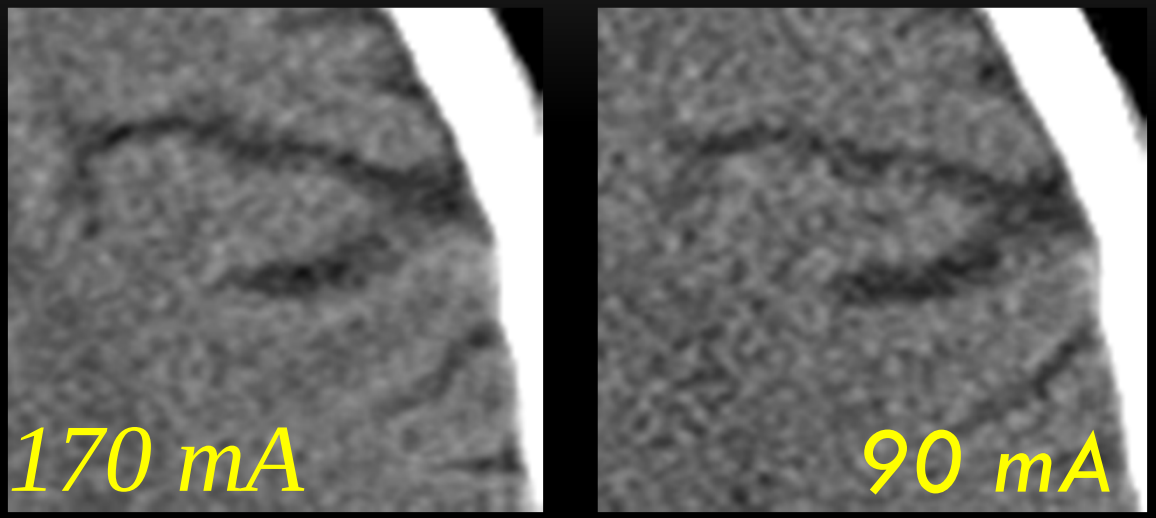
- Beam collimation: Lower is better (16*0.6>>16*1.2)
  - Pros: Less scatter
  - Pros: Better slice selectivity profile
  - Cons: More rotations
  - Cons: Slight dose penalty
- Rotation speed: Fast to minimize motion artifacts
- Reconstruction kernel
  - Softer: thinner slices (CTA) or lower dose
  - 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)

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)

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

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

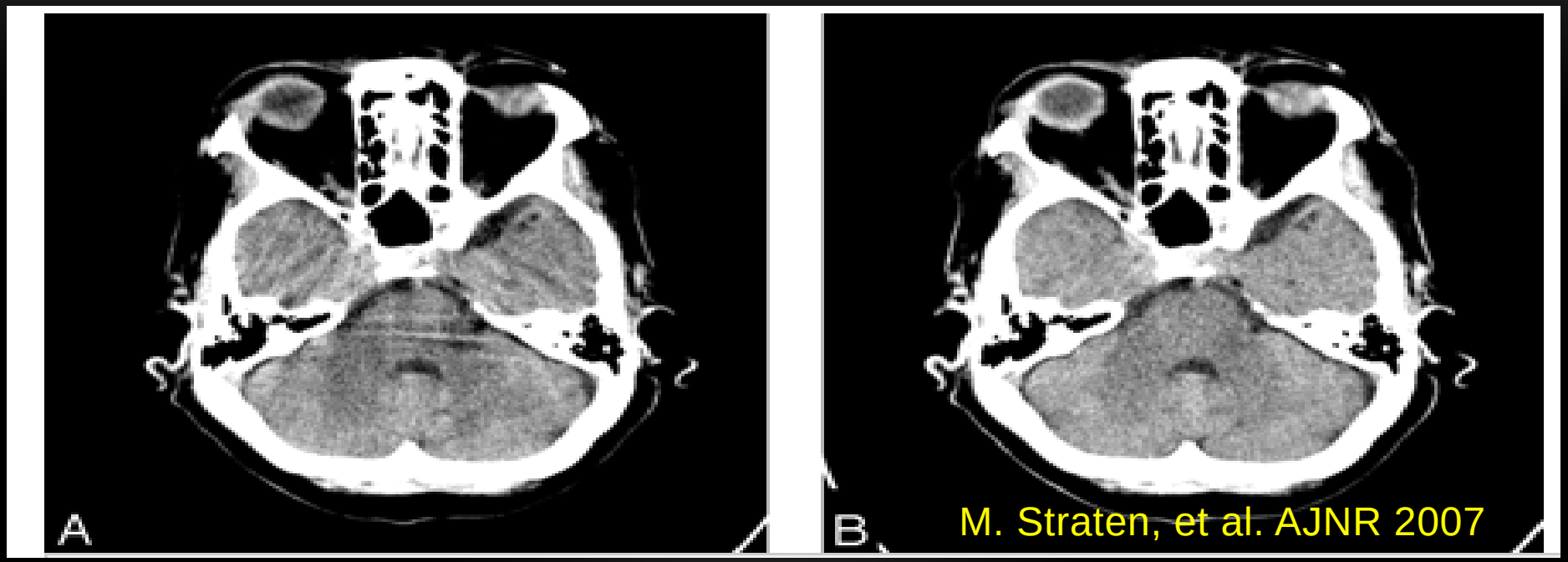
Axial

- 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

AXIAL VS HELICAL: IMAGE QUALITY

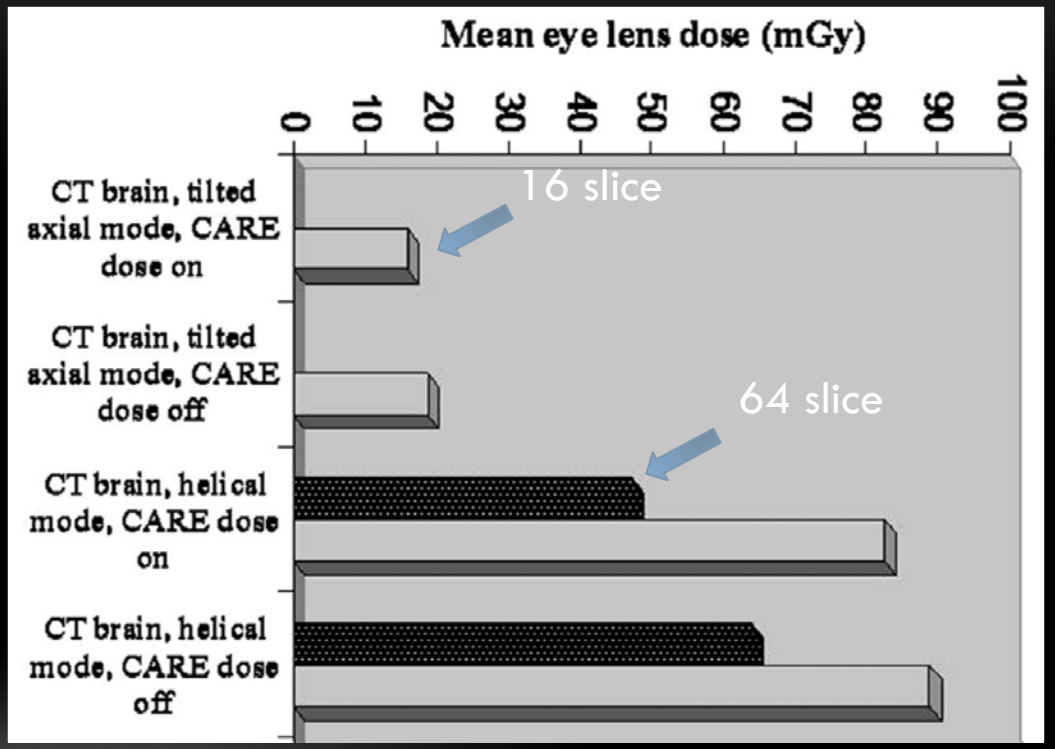


M. Straten, et al. AJNR 2007

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

<u>Sample Neuro Protocols</u>

- 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

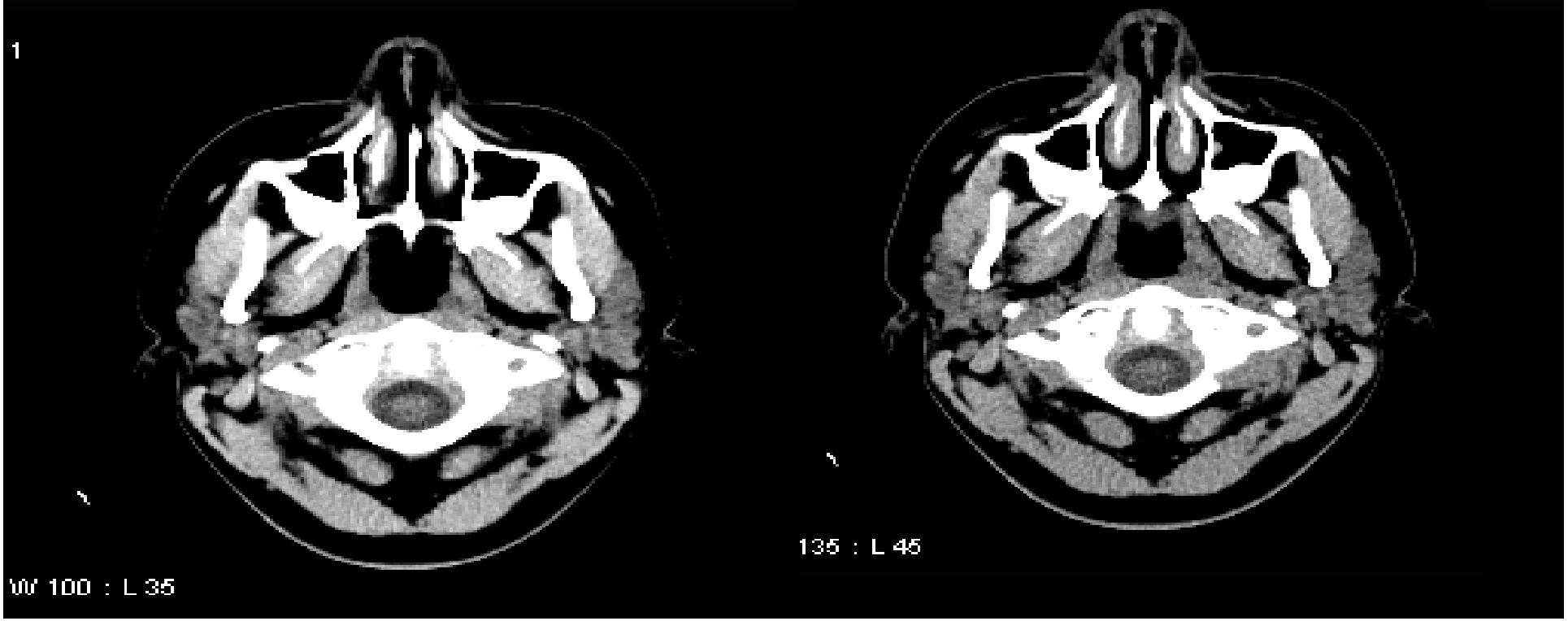
Dose Report

Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
Scout	-	-	-
Helical	I24.000-S108.498	1.78	27.65
		Total Exam DLP:	27.65

POST TRAUMA
120 KVP,0.984P
90-140MA 5NI
5MM-2.5MM

Dose Report

Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
Scout	-	-	-
Helical	I29.250-S130.750	22.12	400.89



SINUS AND ORBITS

Orbit, face, and sinus CT protocols

Series	Scan Type	Detector Configuration	Pitch	Speed	FOV (cm)	kVp	Auto mA			Rotation Time	Section Thickness
							Min	Max	NI		
	Helical	64 × 0.625	0.984:1	49.21	18	120	100	200	12	0.8	1.25

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

Temporal bone CT protocol

Series	Scan Type	Detector Configuration	Pitch	Speed	FOV (cm)	kVp	Auto mA			Rotation Time	Section Thickness
							Min	Max	NI		
	Helical	64 × 0.625	0.984:1	49.21	20	120	100	200	9	0.8	0.625

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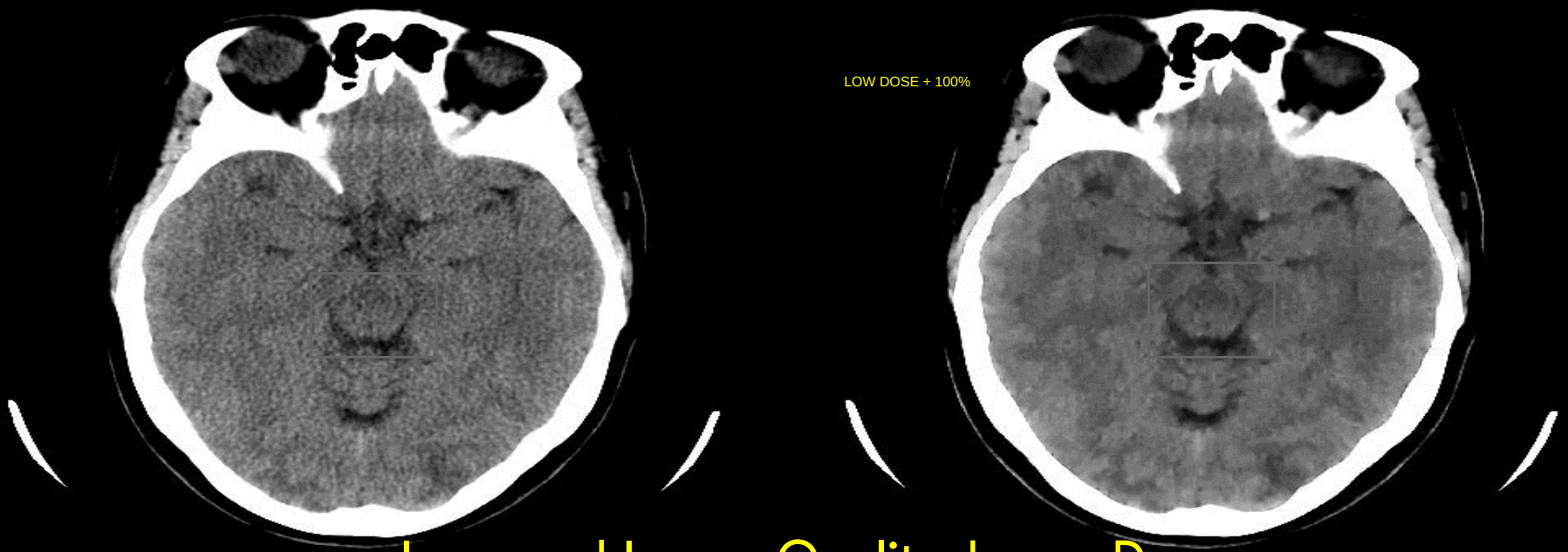
STRATEGY: USE ITERATIVE RECONSTRUCTION WHEN AVAILABLE

Iterative Reconstruction Algorithms

ASIR (GE), IRIS, SAFIRE (Siemens):

(MBIR --- Model Based Iterative Recon)

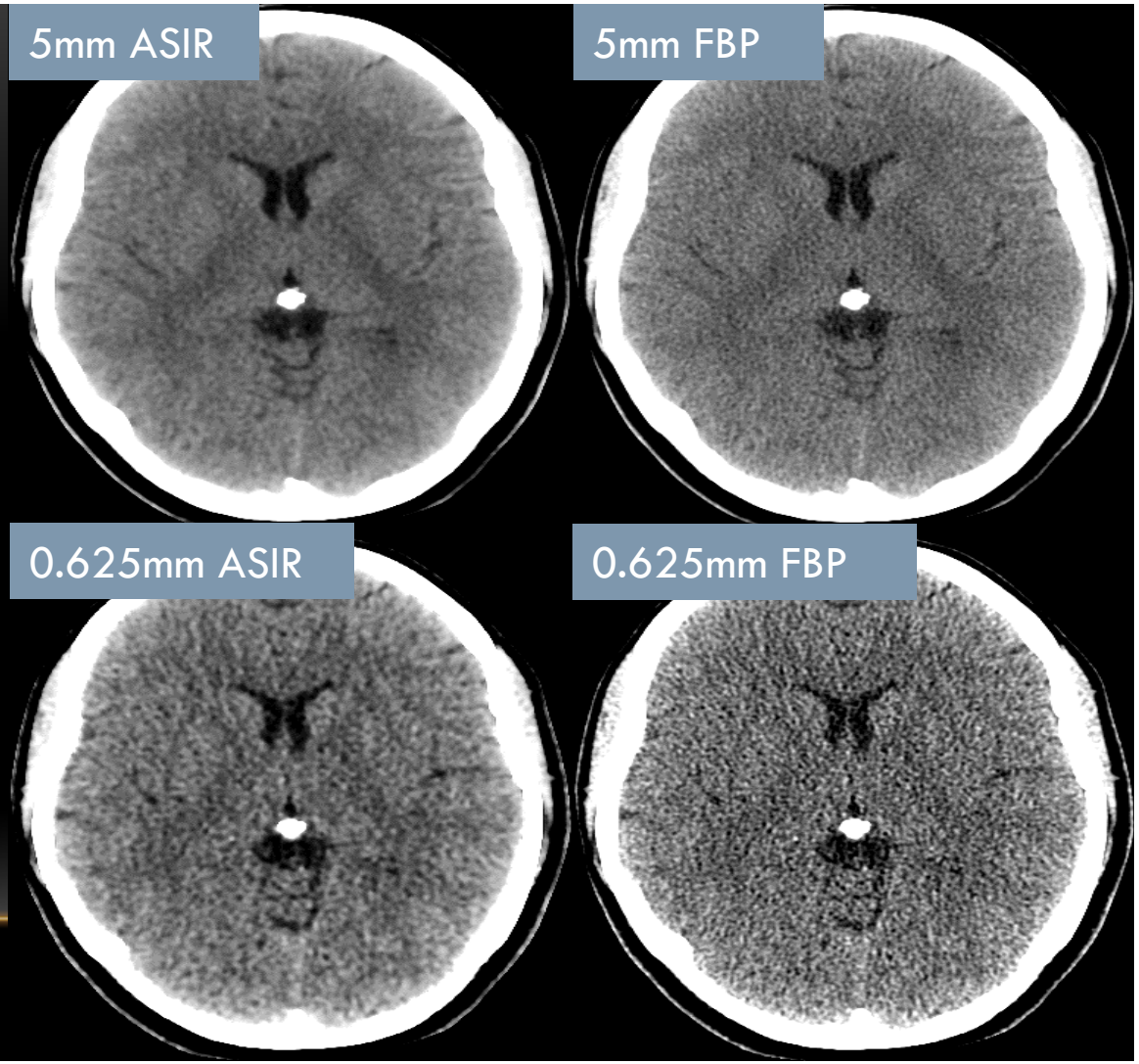


Improved Image Quality, Lower Dose

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 Dsr. Pomerantz & Kamalian, MGH

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

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
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

Reformats	PR
DF	
Thi	
Interval 2.5	
Window Head	

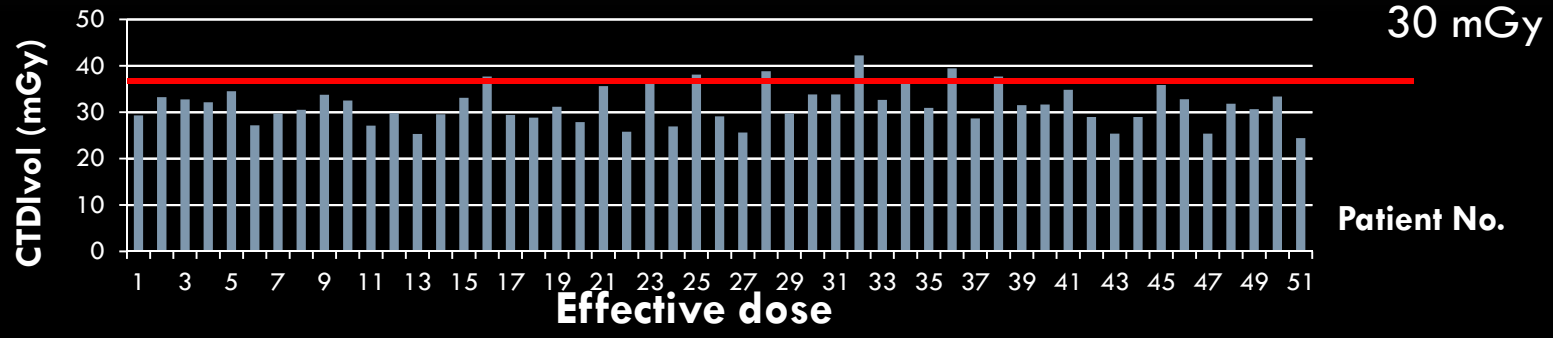
DECRAD CODE: CTBR-

Send dose report to PACS

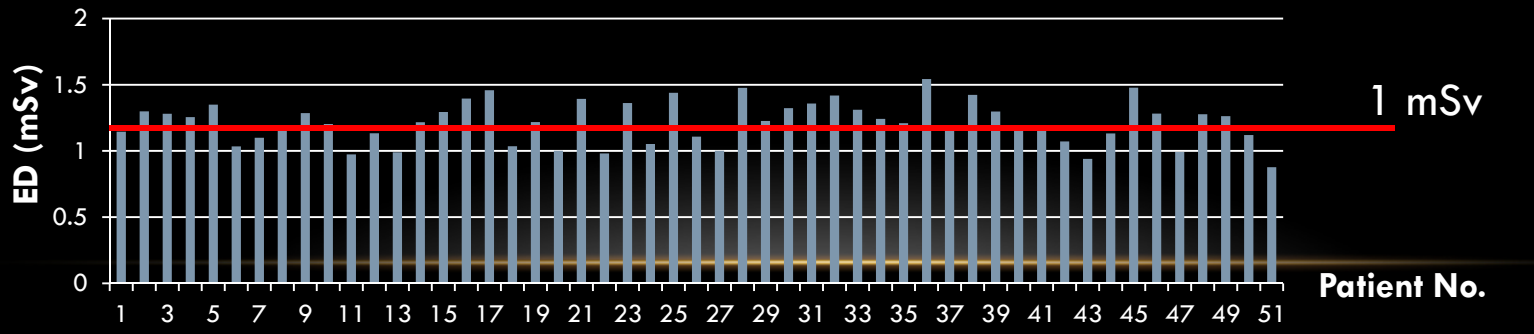
Earlier protocol: No ASIR, fixed tube current
CTDIvol: 67 mGy
Effective dose: 2.6 mSv

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

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



Effective dose



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