

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



100% Dose



50% Dose 20s Later



50% Dose Denoising

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

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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



The screenshot shows the Good Housekeeping website interface. At the top, there is a navigation bar with links for 'SUBSCRIBE', 'Games', 'Win Promotions', 'Give a Gift', 'Video', 'Digital Edition', and 'iPhone App'. Below this is the 'Good Housekeeping' logo. A search bar is present with a 'Try:' dropdown menu showing 'Master Bedrooms', 'Get Organized', and 'Best Anti-'. A secondary navigation bar includes categories: 'Food & Recipes', 'Home & Organizing', 'Diet & Health' (highlighted in pink), 'Beauty & Anti-Aging', and 'Family &'. The article title is 'Overexposed: The Startling Truth About CT Scans' by Melody Petersen. The article text discusses the increase in CT scans and the risk of cancer. Below the text is a grid of six CT scan images of the brain. To the right of the images is a text snippet starting with 'When the doctor told Alexandria Cody she needed to have a CT scan "right now," she and her husband headed straight for a hospital near their Hopkins, MN, home. They were worried about the cost — they'd had no health insurance since Cody, 55, had been laid off from her job as an administrative assistant and her husband had retired from a car dealership. But the doctor's tone was so urgent, they didn't'.

ROE

Browser address bar: roe.partners.org/ChooseInstitution.aspx
Browser toolbar: AM, MP, AAPM, NIBIB, ICRU, f, o, Windows, Mail, RSS, ppd, Insight, VPN, J, T Lib, Pub, SP, Hub



Radiology Order Entry



Select a hospital to work with:

Mass General Hospital >

Newton Wellesley Hospital >

Authentication Required [X]

? Enter username and password for http://mgхроe

User Name:

Password:

OK Cancel

Courtesy of Sarabjeet Singh, MD

ROE: SELECT A MODALITY AND A BODY PART

PATIENT NAME: TEST, IGNORE DOB: 03/09/1973 Gender: M		MRN: 000006	ORDERING PHYSICIAN: Gupta, Rajiv
Collapse ^ Order a New Exam			
Bone Densitometry ▶	Head/Neck ▶	Head CT	
Cardiac Stress Testing ▶	Chest ▶	Face or Sinus CT	
CT ▶	Cardiac ▶	Neck CT	
Fluoroscopy ▶	Abd/Pelvic ▶	CTA: Head/Neck	
Interventional Procedures ▶	Spine ▶	CT Dental Scan	
Mammography ▶	Extremity ▶		
MR ▶	PET CT ▶		
Nuclear Medicine ▶	QCT ▶		
Plain Film ▶			
Ultrasound ▶			
Vascular Testing ▶			

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
<input checked="" type="radio"/> CT Head	CT Head or Brain
<input type="radio"/> CT Head & Neck	CT Head or Brain and CT Neck
<input type="radio"/> Pediatric Head for Craniosynostosis	CT Head or Brain without contrast and 3D reconstructions
<input type="radio"/> Pediatric Head for Trauma	CT Head or Brain without contrast
<input type="radio"/> 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

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)
- Episode of lost consciousness
- Ammenorrhea
- 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
- Aneurysm
- Arterial-venous malformation(AVM)

Known Diagnoses (not rule/out!)

Courtesy of Sarabjeet Singh, MD

ROE: SHOWS PREVIOUS EXAMS

The screenshot shows a software window titled "MGH ROE" with a "RADIATION ALERT!" dialog box. The alert text states: "The patient had **4 previous CT Scans** (*more info*) at Partners Imaging Centers." Below the alert is a table listing the previous exams:

Exam Description (Site)	Scheduled Date
AbdCTw/contr &PeIcTw/contrast_ (MGH)	11/22/2006
CT Bone Mineral (MGH)	01/20/2006
CT Bone Mineral (MGH)	01/19/2006
CT CHEST- (MGH)	08/08/2003

At the bottom of the dialog box, there is a prompt: "Click 'OK' to proceed to order the exam or 'Cancel Exam' to cancel the exam:" and two buttons: "OK" and "Cancel Exam".

Courtesy of Sarabjeet Singh, MD

ROE: EVIDENCES-BASED APPROPRIATENESS

The screenshot displays the MGH ROE interface. At the top, the browser title is "MGH ROE". The main content area features a utility score of 9, which is highlighted in green. Below the score, a legend indicates that scores 7-9 are "Indicated", 4-6 are "Marginal", and 1-3 are "Low Utility". The score 9 is in the "Indicated" range. To the right of the score, there are three options: "Proceed with exam", "Cancel or select new exam", and "Change indications and resubmit". Below the score, there is a section for "Alternate procedures to consider:" with a list containing "MR" and "6". At the bottom of the interface, there is a patient information section with fields for "PATIENT NAME: TEST, IGNORE", "DOB: 03/09/1973", "Gender: M", "MRN: 000006", and "ORDERING PHYSICIAN: Gupta, Rajiv". Below this, there are buttons for "Proceed", "Cancel", "Change", and "Create Exam Template". In the bottom right corner, there is a link for "Clinical Consultation ROE Help Managing and Creating Templates".

Head CT is indicated for the clinical indications provided

9 8 7 6 5 4 3 2 1

Indicated 7-9 Marginal 4-6 Low Utility 1-3

Options:

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

Alternate procedures to consider:

- MR
- 6

PATIENT NAME: TEST, IGNORE
DOB: 03/09/1973 Gender: M MRN: 000006 ORDERING PHYSICIAN: Gupta, Rajiv

Proceed Cancel Change Create Exam Template

Clinical Consultation
ROE Help
Managing and Creating Templates

Head CT

Courtesy of Sarabjeet Singh, MD

Select Site and Schedule Exam

EXAM	LOCATION	DATE/TIME	BILLING	PREAUTHORIZE CODE
HEAD CT	TBD	TBD	BILLING AND INSURANCE UPDATES	

Location	Search Calendar	First Available
Boston-Main Campus		Thu 3/7/2013 5:45 PM <input type="button" value="Schedule"/>
Boston-Yawkey Center		Fri 3/1/2013 4:00 PM <input type="button" value="Schedule"/>
Chelsea		Tue 2/26/2013 1:00 PM <input type="button" value="Schedule"/>
Danvers (MGH/NS)		Wed 2/27/2013 3:00 PM <input type="button" value="Schedule"/>
Waltham		Tue 2/26/2013 1:45 PM <input type="button" value="Schedule"/>
Worcester		Tue 2/26/2013 1:15 PM <input type="button" value="Schedule"/>
Nantucket Cottage Hospital		Tue 2/26/2013 2:00 PM <input type="button" value="Schedule"/>

stress - /36.4

<input type="checkbox"/> Cancel	3/7/2013 5:45 PM Boston-Main Campus	<ul style="list-style-type: none">Contrast use at Discretion of RadiologistCT Head	<ul style="list-style-type: none">Head injury mild or moderate acute, no neurological deficit - 959.01	Gupta, Rajiv	ss272 (Site: MGH) 2/26/2013 11:05 AM
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[Reschedule](#)

[Schedule/Reschedule Multiple Exams](#)

[Print Instructions For All Scheduled Exams](#)

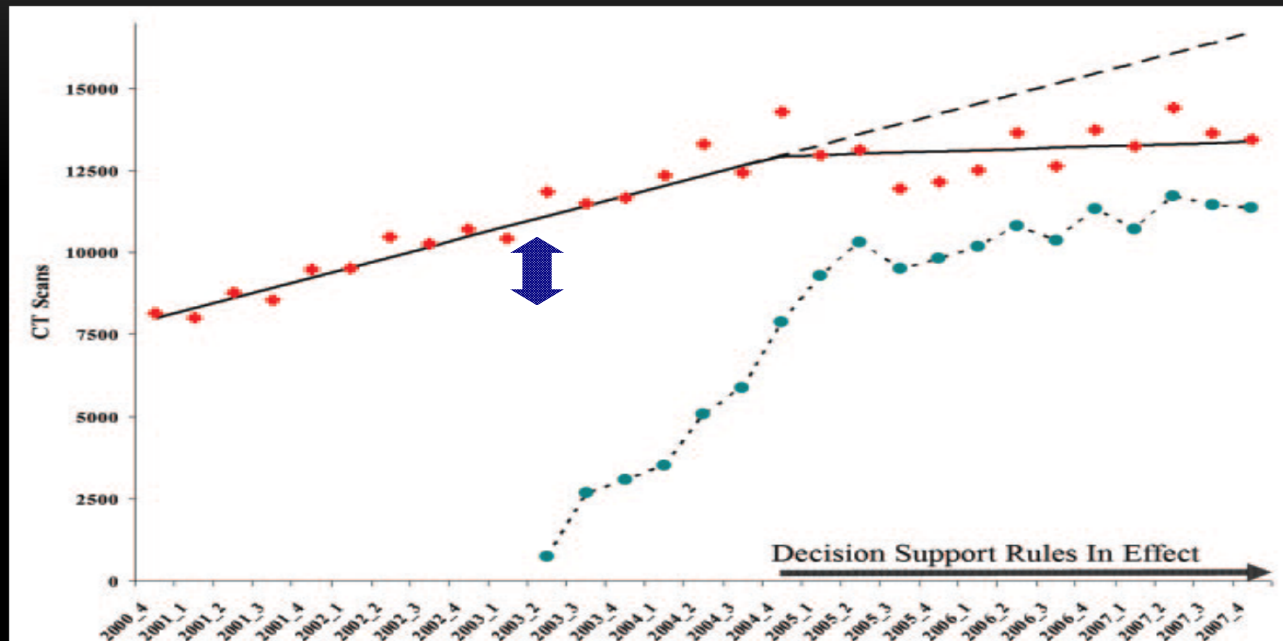
To schedule or reschedule multiple exams select up to 3 above.

[Pending Exams](#)

[Recent Exams](#)

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.

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100% Dose

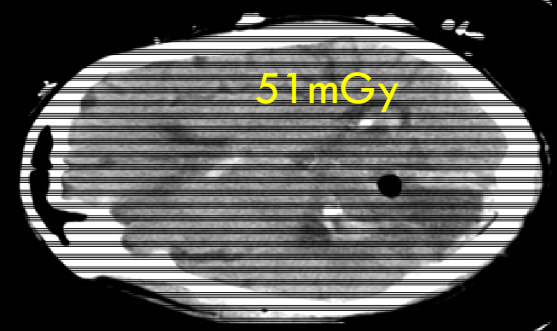
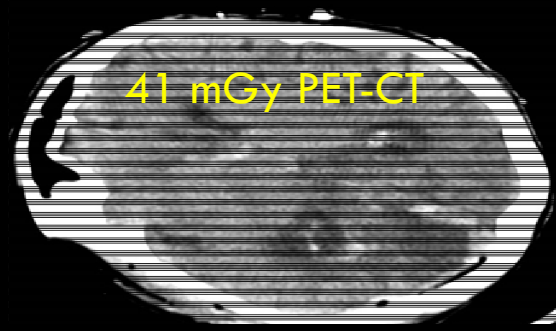
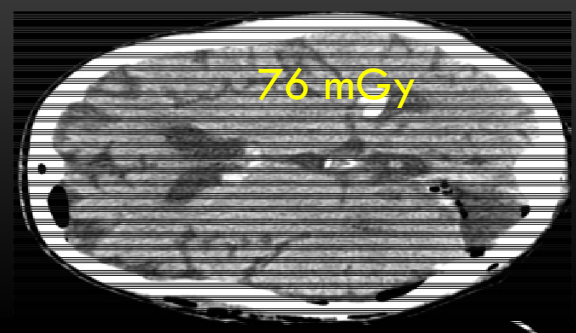
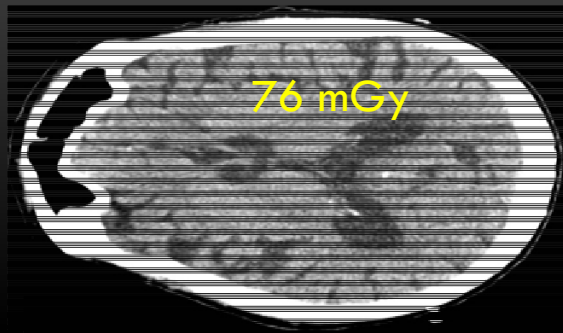
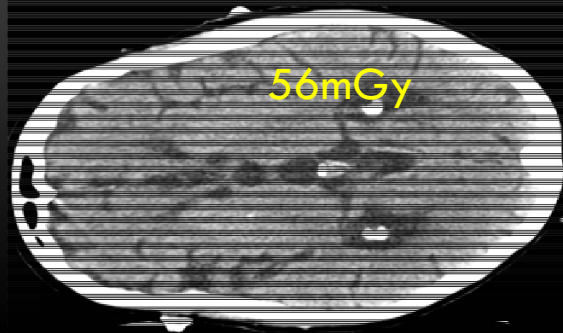


50% Dose 20s Later

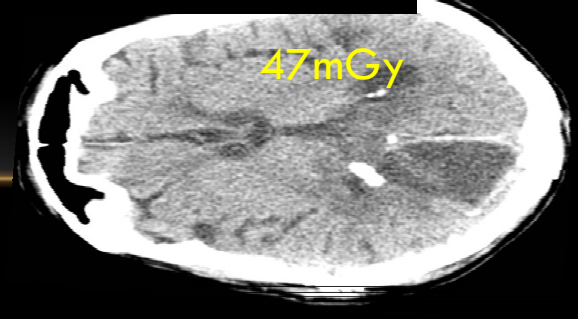
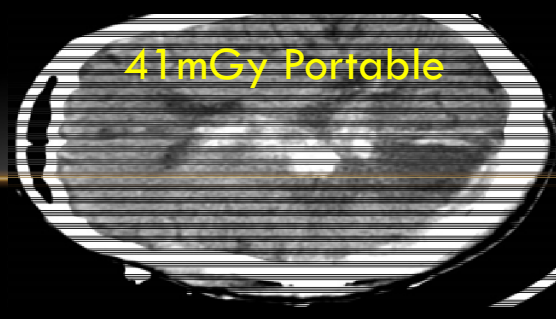
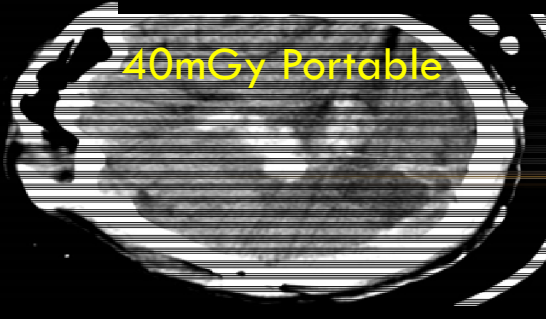


50% Dose Denoising

**STRATEGY: ACQUIRE EACH SCAN WITH
CARE AND LOVE**



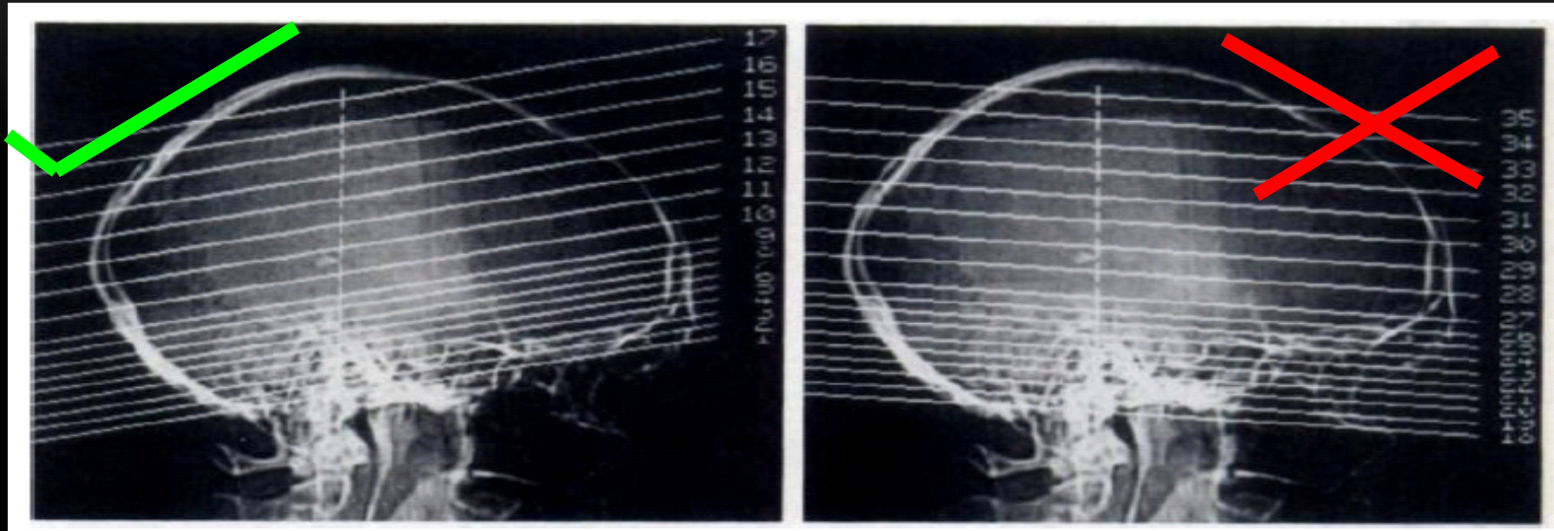
CT Tech is the #1 determinant of Image Quality



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

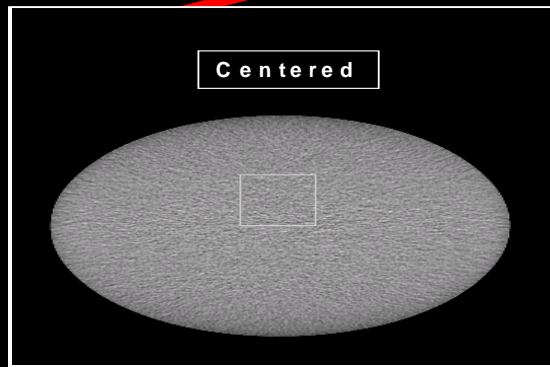
- 95% patients are off-centered in CT
- Dose up by 3-30% due to bow tie

Off centering
Noise

Noise increase 30%

Noise increase 22%

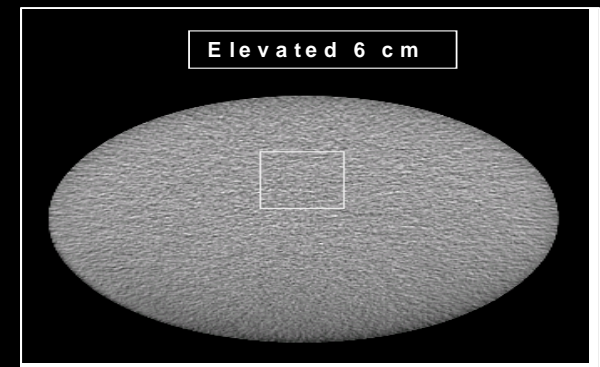
Elliptical phantom



30 x 21.5 cm phantom



Effective mA loss
50%



Effective mA loss
70%

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 ($16 \times 0.6 \gg 16 \times 1.2$)
 - 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

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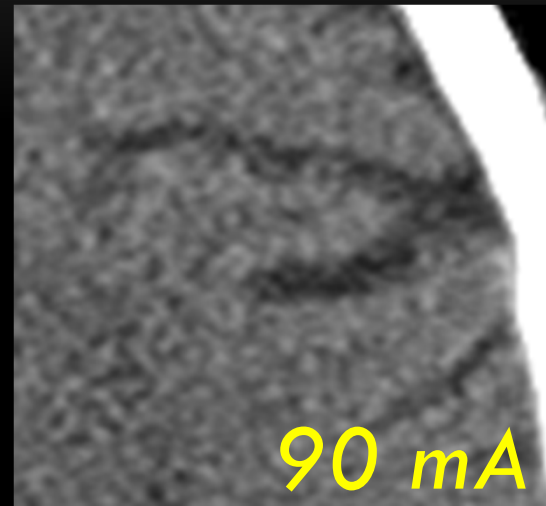
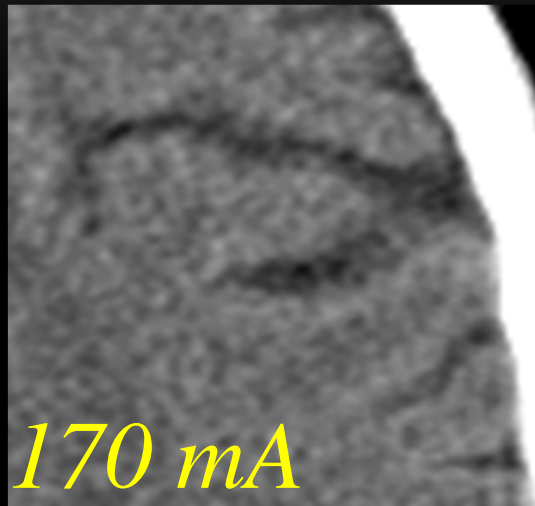
50% Dose Denoising

**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 $\sim 1 / \text{SQRT}(\text{mAs})$

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
- 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

Smith, Dillon, Wintermark et al. Radiology 2008

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

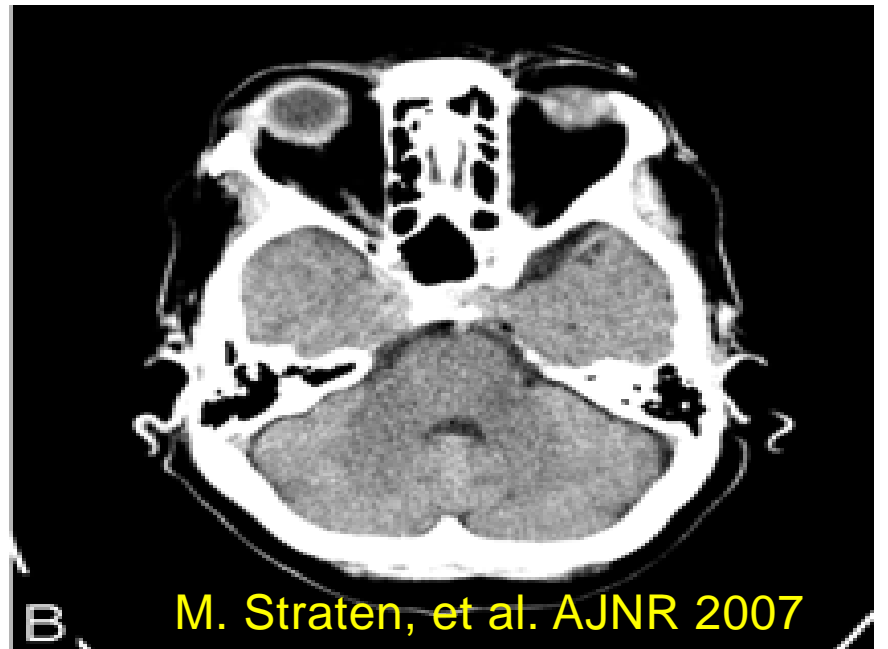
Axial

- 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

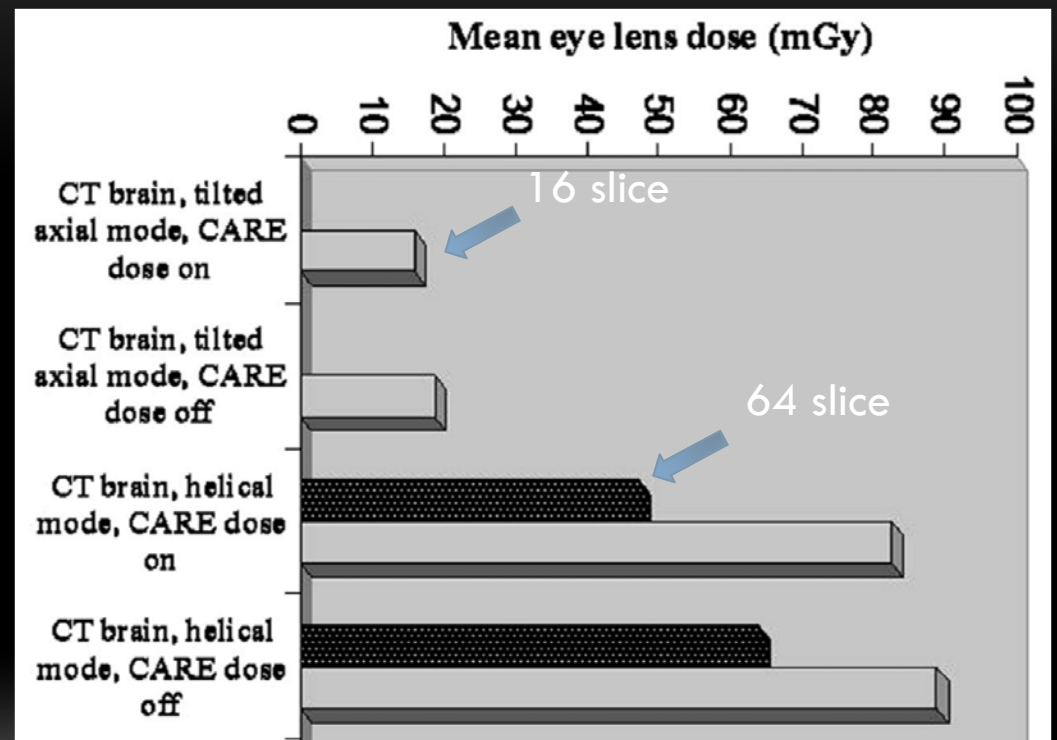


M. Straten, et al. AJNR 2007

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)



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

Dose Report			
Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
Scout	-	-	-
Helical	124.000-S108.498	1.78	27.65
Total Exam DLP:			27.65

1



WV 2362 : L 439



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	129.250-S130.750	22.12	400.89

1



W 100 : L 35



135 : L 45

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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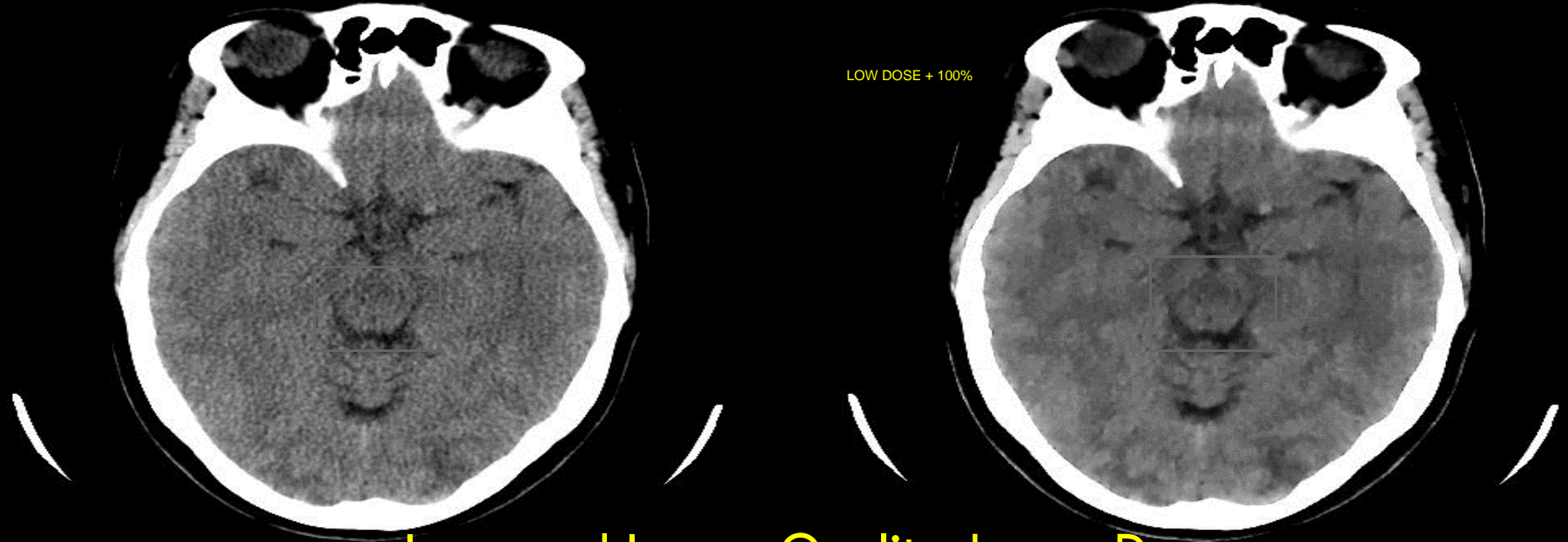


50% Dose Denoising

**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

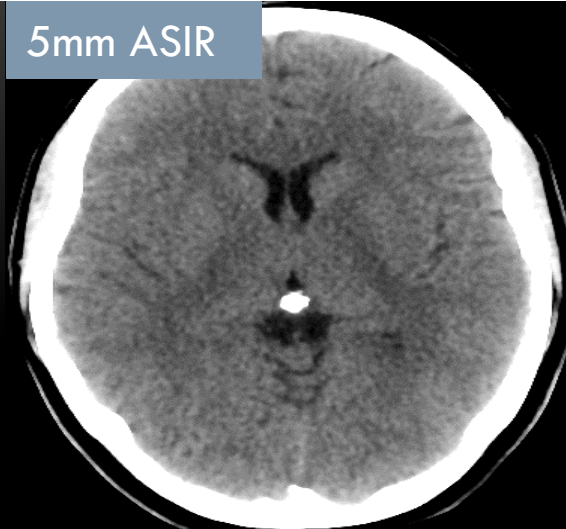
CDTIvol: 28.82 mGy

DLP: 522.47 mGy.cm

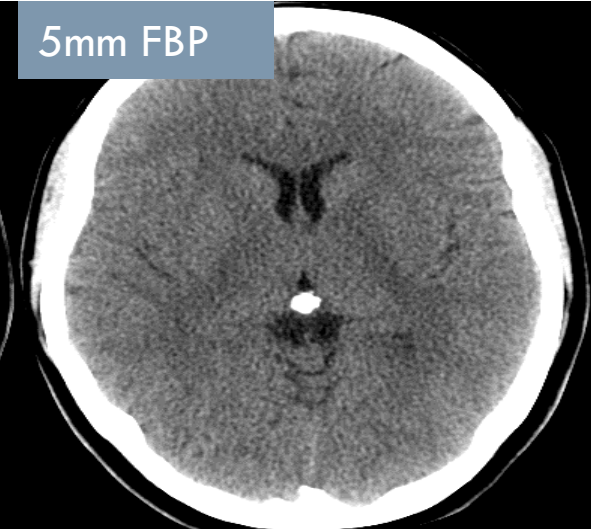
Effective Dose: 1.09 mSv

(Conversion factor
0.0021)

5mm ASIR



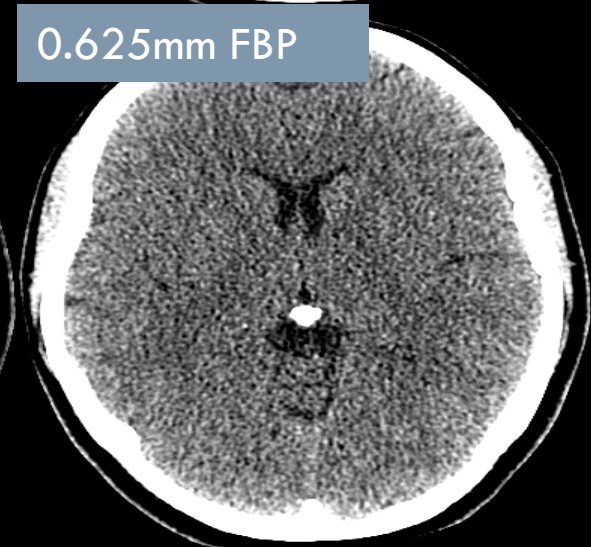
5mm FBP



0.625mm ASIR



0.625mm FBP



Courtesy of Dsr. Pomerantz &
Kamalian, MGH

SAMPLE CT DOSE REDUCTION AT 30% ASIR

HEAD
SPINE

		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	
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

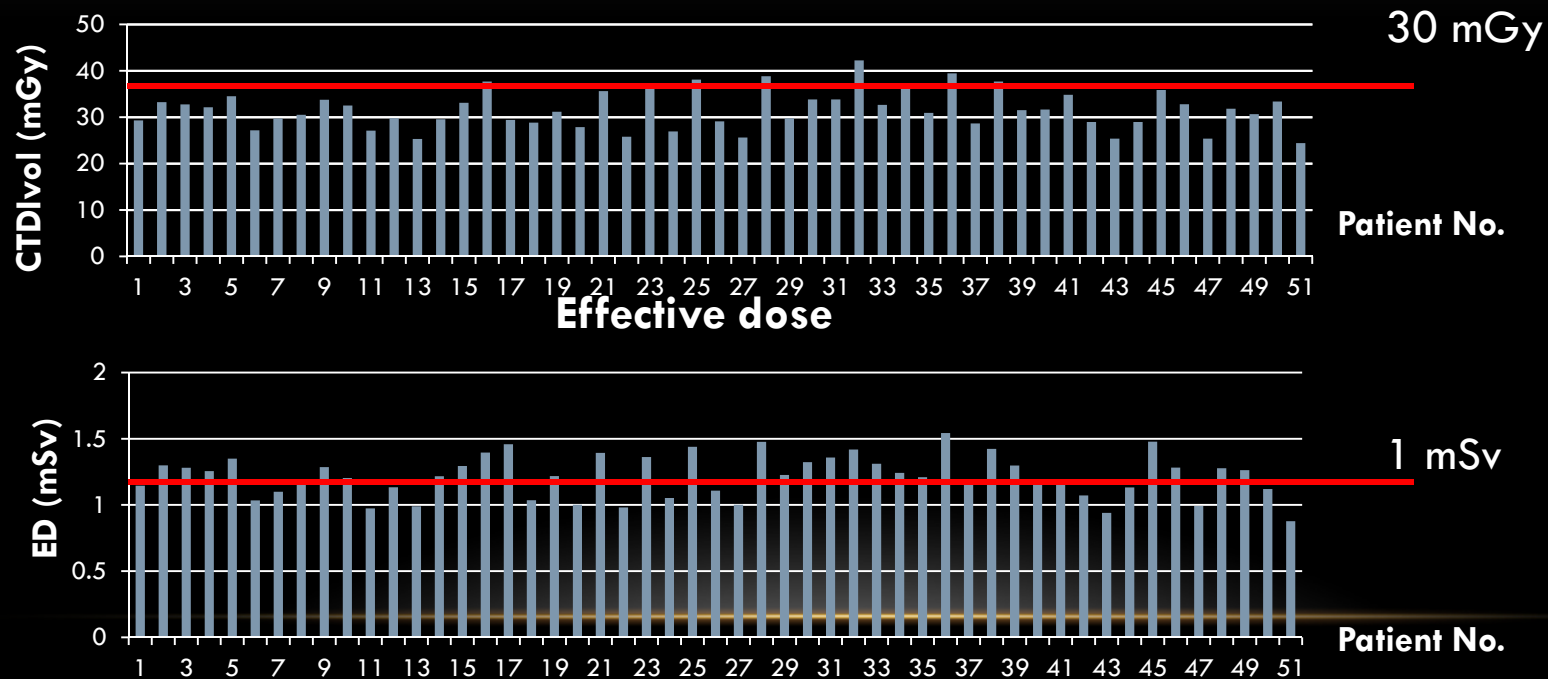
SAMPLE MGH 64-SLICE HEAD CT PROTOCOL (MINOR VARIATIONS BETWEEN SCANNERS)

Series Auto Transf		OFF	
Mode		Helical	
Time		0.7	
DMPR		ON	Helical,
Thickness		1.25	120kV,
Pitch		0.531:1	Auto-mA,
Speed		10.62	Pitch 0.5,
Interval		0.625	ST 1.25,
Rotation Time		0.7	interval 0.625
Gantry Tilt		0	
SFOV		Head	
KV		120	
mA		250	
DFOV		22	
ALG		Standard	
Recon 2:		Reformats	PR
5 MM DX STD AXIALS		DF	
Thickness	5.0	Thi	
Interval	5.0	Interval 2.5	
Algorithm	22	Window Head	
DFOV	Std		
Recon 3:			
2.5 MM DX BONE AXIALS			
Thickness	2.5		DECRAD CODE: CTBR-
Interval	2.5		Send dose report to PACS
Algorithm	Bone		
DFOV	??		

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



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