How Dose Tracking Affected Protocol Optimization in a ~~Tertiary~~ Quaternary Healthcare Center

Mannudeep K. Kalra, MD
Webster Center for Quality and Safety
Massachusetts General Hospital
Harvard Medical School

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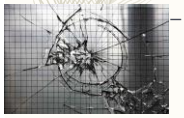
Dose Tracking at MGH

- Software
  - Radimetrics, Bayer
  - ACR Dose Index Registry

Tracking and Cracking: Personnel

- Medical Physicist (PhD: Lead)
  - *Dose tracking (Radimetrics)*
  - *ACR DIR*

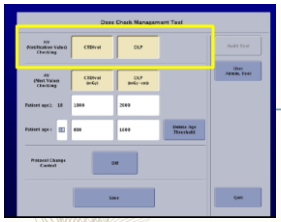


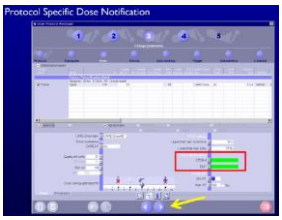
- CT Quality Assurance Manager (RTR - CT)
  - *Protocol maintenance*

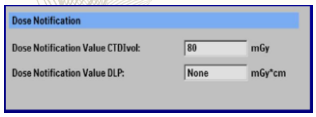
ADULTS.....CT	CTDI vol Notification Value
Head	80 (16 cm)
Neck AND C -Spine	30 (32 cm)
Neck CTA	50 (32 cm)
Abdomen-Pelvis AND L-Spine	30 (32 cm)
Chest AND T-Spine	30 (32 cm)
Extremities	30 (32 cm)
Brain Perfusion	600 (16 cm)
Cardiac/Vascular Prospective (sequential)	50 (32 cm)
Cardiac/Vascular Retrospective (spiral)	150 (32 cm)

Children.... CT	CTDI vol Notification Value
Abdomen-Pelvis AND L. Spine	20 (32 cm)
Chest- T. Spine	20 (32 cm)
Extremities	20 (32 cm)
Head	40 (16 cm)
Neck AND Spine	40 (16 cm)
Cardiac/Vascular Prospective (sequential)	50 (32 cm)

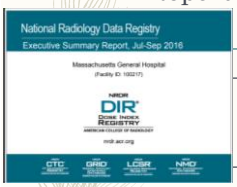
Scanner Notification



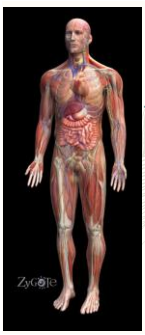




Reports

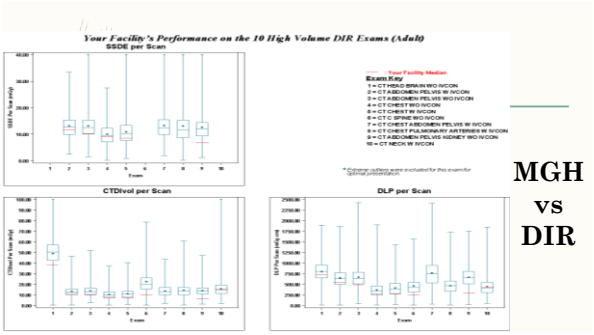


- Weekly/Quaterly review of Dose tracking
  - Medical Physicist
  - CT QA manager
- Quarterly review of Doses from ACR DIR
  - Medical physicist
  - Radiology Quality and Safety Committee

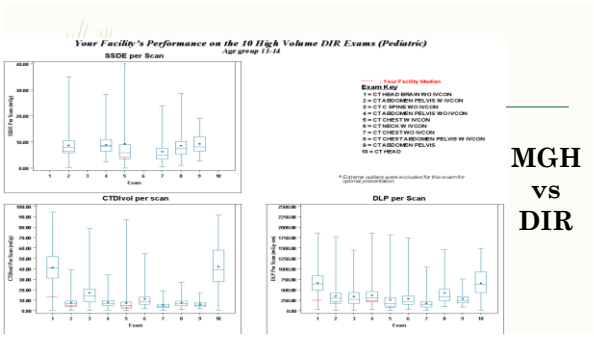


Issues with Reports: Radiologists

- Abdominal
- Cardiac and Vascular
- Emergency
- Chest
- Neuroradiology – Separate personnel for Adults & Children
- Pediatrics
- Musculoskeletal

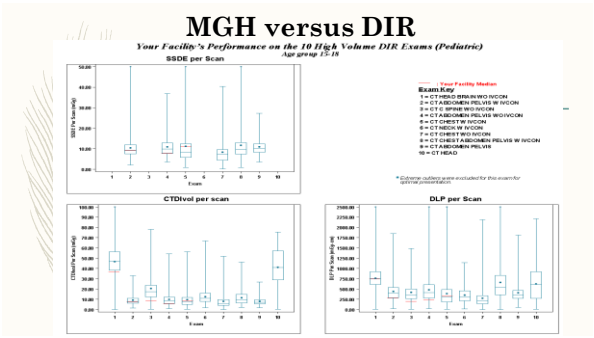


MGH vs DIR



MGH vs DIR

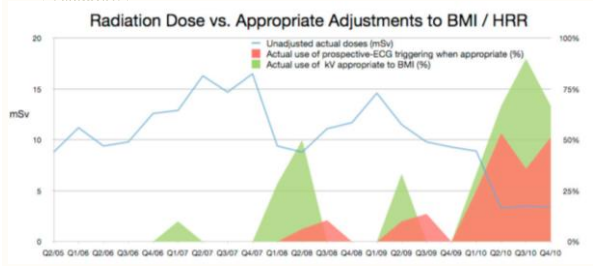
MGH versus DIR

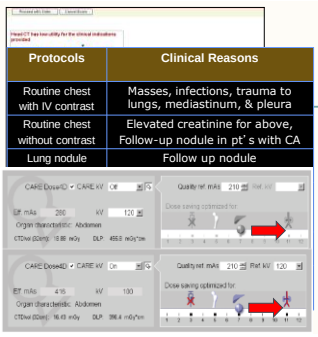


MASSACHUSETTS GENERAL HOSPITAL
IMAGING

At Mass General, radiation dose for CT scans are 30% to 95% lower than national averages. We customize each scan to achieve the lowest radiation dose possible.

Cardiac CT Dose Tracking





Protocols	Clinical Reasons
Routine chest with IV contrast	Masses, infections, trauma to lungs, mediastinum, & pleura
Routine chest without contrast	Elevated creatinine for above, Follow-up nodule in pt's with CA
Lung nodule	Follow up nodule

Sequence of Dose Utilization

1. **Appropriateness**
   - Just Right Indication with Decision Support
2. **Indication based dose optimization**
   - CT protocols based on clinical indications
3. **Patient size based dose adjustment**
   - Separating children from adults
   - Automatic exposure control
   - Automatic tube potential selection

Kalra et al. Radiographics 2015

Issues with Dose Tracking

- Variety of CT scanners
- Variety of CT protocols
- Multi-phase or multiple-run CT
- Bariatric patients
- Hardware
- Arms in wrong places- by side of body or head

Scanners

Modality	Site	Location	Vendor	Description	Slice	Source	Iterative Reconstruction	Dicom SR Reporting	Pedi/adult ref protocols	CT Dose Check	AEC
CT1B2	Main	Blake 286A	Siemens	Siemens Sensation Cardiac 64	64	Single	NO	YES	YES	YES- operator alerts	YES
CT2B2	Main	Blake 287A	Siemens	Somatom Definition Flash	128	Dual	YES- Safire	YES	YES	YES- operator alerts	YES
CT3B2	Main	Blake 288B	Siemens	Siemens Somatom Definition Edge	128	Single	YES- Safire	YES	YES	YES- operator alerts	YES
CT4B2	Main	Blake 288A	GE	GE Discovery CT750 HD	64	Dual	YES- ASIR	YES	YES	YES- operator alerts	YES
CT1E2	Main	Ellison 228	GE	Lightspeed16	16	Single	NO	YES	YES	YES- operator alerts	YES
CT2E2	Main	Ellison 230	GE	Lightspeed Pro 16	16	Single	NO	YES	YES	YES- operator alerts	YES
CT1G2	Main	Gray 2	GE	Lightspeed Xtra	16	Single	NO	YES	YES	YES- operator alerts	YES
CT1W1	Main	White 190	GE	Lightspeed VCT	64	Single	YES- ASIR	YES	YES	YES- operator alerts	YES
CT2W1	Main	White 192	Siemens	Siemens Force	192	Dual	YES- ADMIRE	YES	YES	YES- operator alerts	YES
CT1Y6	Main	Yawkey 6422	GE	Lightspeed Pro	16	Single	NO	YES	YES	YES- operator alerts	YES
CT2Y6	Main		GE	Revolution CT	512	Single	YES- ASIRV	YES	YES	YES- operator alerts	YES
CT1Y3	Main		PlanMed	Verity		Single	NO	YES	YES	YES- operator alerts	YES
CTPOR	Main	Neuro ICU	Samsung	Ceretom	8	Single	YES	YES	YES	YES- operator alerts	YES
CT1L4	Main	Lunder 4	Siemens	Sensation Open (intraop)	40	Single	NO	YES	YES	YES- operator alerts	YES
CT0L6	Main	Lunder 6	Siemens	Biograph	64	Single	NO	YES	YES	YES- operator alerts	YES
PET0MG	Main	Blake 2	Siemens	Biograph	64	Single	NO	YES	YES	YES- operator alerts	YES
Outpatient Imaging Centers											
CT1NS	Danvers	Danvers	GE	Lightspeed VCT	64	Single	NO	YES	YES	YES- operator alerts	YES
PETCT1NS	Danvers	Danvers	Siemens	Biograph mCT Flow	64	Single	YES- Safire	YES	YES	YES- operator alerts	YES
CT1CH	Chelsea	Chelsea	Philips	Philips Brilliance 256	256	Single	YES- I Dose	YES	YES	YES- operator alerts	YES
PET1CH	Chelsea	Chelsea	GE	Discovery PET/CT VCT	64	Single	NO	YES	YES	YES- operator alerts	YES
CT1WA	Waltham	Waltham	GE	Discovery CT750 HD	64	Dual	YES- ASIR	YES	YES	YES- operator alerts	YES
	Waltham	Waltham		PedCAT							
CT1NCH	Nantucket	Nantucket	Philips	Brilliance 40	40	Single	NO	NO	YES	NO	YES
MVHCT1	MVH	Martha's Vineyard	GE	Lightspeed VCT	64	Single	YES- ASIR	YES	YES	YES- operator alerts	YES

- 24 CT
- GE
- Philips
- Siemens

Sorting Protocols

	Protocols	NEW BOOK	GE64	GE64 HD	Philips 40	Phillips 256	Siemens 64	Siemens Edge	Siemens Flash	Siemens Force
2	**ABD pelvis cancer follow up ART-PV**	X	X							
3	**ABD pelvis cancer follow up**	X				X		X		
4	ABD-pelvis routine ART(DE)-PV_under 250 lbs					X				X
5	**ABD pelvis routine ART-PV**	X		X						X
6	ABD-pelvis routine ART-PV_over 251 lbs		X		X	X	X			
7	ABD-pelvis routine W-ASIR								X	
8	ABD-pelvis routine NO ASIR		X							
9	**ABD pelvis routine**	X	X							
10	ABD-pelvis routine PETCT			X	X	X	X	X	X	X
11	**Adrenal mass**	X	X							
12	APPY appendicitis		X	X		X	X	X	X	X
13	APPY oral							X	X	
14	APPY rectal						X			
15	**APPY protocol**	X					X			
16	Bariatric (GE) ABD-pelvis		X	X						
17	Bladder_CA ABD-pelvis			X						
18	**Bladder CA protocol**	X				X				
19	Cancer follow-up ART(DE)-PV(DE)_under 251 lbs		X				X	X	X	X
20	Cancer follow-up ART(DE)-PV(DE)_over 251 lbs			X					X	
21	Cancer follow-up ART-PV								X	
22	Cancer follow-up ART-PV_over 251 lbs		X		X		X			
23	Cancer follow-up_over 251 lbs			X						
24	Cancer follow-up(DE)_under 250 lbs								X	
25	Cancer follow-up_over 251 lbs			X						
26	Cancer follow-up			X						
27	Cancer follow-up w/o contrast		X		X		X	X		X
28	**Colonography DIAG/DX**									X
29	Colonography Research_GE64		X	X		X	X	X	X	X
30	CTA Kidney Transplant			X						
31	**Cystogram**	X	X							
32	Dual Phase Liver: ART/PV ABD-pelvis		X	X			X	X	X	

G1-ABD-PEL / G2-ABD-PEL NAME-SERIES / CHEST / VASC-CARDIAC / BONE-MSK / NEURO / PEDI NEURO / PEDI BODY

- Multiple protocols
- Multiple nomenclature

Series 2:	CTA H&N T-SNS	
Location		Vertex to Arch
Care Dose 4D	ON	450
Care kV	SEMI	Ref. 100
ACQ		128X.6 MM
Rotation Time		0.5
Pitch		0.8
Direction		Crainalcaudal
Slice Thickness		1 mm
Slice Increment		.6 mm
Kernel		H45
Window		CT Angio
Safire		OFF
FOV		230
API		NONE
Series Transf.		On for all series
Dose Optimizer		11
Series 3 Delays:	**(Immediate)**	**DELAY THINS S3**
Location		COW to Arch
Care Dose	ON	QRM 450
Care kV	ON	Ref 100
ACQ		128X.6 MM
Rotation Time		0.5

CTA- Head and Neck

DLP above the 75th percentile in ACR DIR

- Non contrast CT
- Post contrast arterial phase
- Delayed phase

Trouble shoot

- Reduce kV
- Reduce dose for non-contrast and delays

Bariatric Issues

Date/Time	###########		
Event Initiator	New Patient		
Event Type	Dose Check		
Diagnostic Reason	pt body habitus. pt weight is 395lbs		
Operator ID	gs		
Exam Number	1619		
Protocol Selector	User	Protocol Category	Adult
Protocol Number	6.7	Protocol Name	ED ABD-PEL ROUTINE <301 LBS 5/2016
Series#	2	Series Description	ABDOMEN PELVIS
	Images	NV	Projected
CTDIvol (mGy)	1 - 204	30	32.78

Date/Time	12/13/2016 0:48		
Event Initiator	New Patient		
Event Type	Dose Check		
Diagnostic Reason			
Operator ID	KAS		
Exam Number	1544		
Protocol Selector	User	Protocol Category	Adult
Protocol Number	5.12	Protocol Name	TRAUMA CHEST/ABD/PELVIS (arms up) >300 lbs 5/2016
Series#	2	Series Description	TRAUMA C/A/P I+ 2.5cc/sec
	Images	NV	Projected
CTDIvol (mGy)	145 - 355	30	31.8

CT Myelogram

- Frequent culprit
- Particularly with hardware

Date/Time	2016-12-29 11:13		
Event Initiator	New Patient		
Event Type	Dose Check		
Diagnostic Reason	HARDWARE MYELO		
Operator ID	SM		
Exam Number	30000		
Protocol Selector	User	Protocol Category	Adult
Protocol Number	7.14	Protocol Name	T/L SPINE POST MYELO HD HARDWAR E (Dr.Hunter) 8/2016
Series#	4	Series Description	0.625 mm HI RES STD
	Images	NV	Projected
CTDIvol (mGy)	1 - 983	40	54.52

High Frequency Issues

MGH Imaging CT Dose Quarterly Review Report

For high dose body cases, three major challenges:

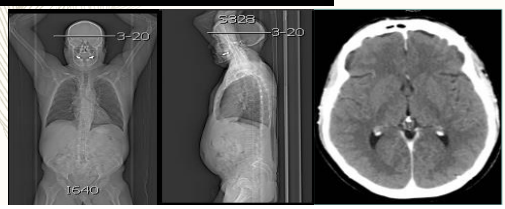
1. CTA NECK W/DELAYS 9/2015 (CT1Y6): shoulders included for TCM.
2. Myelogram: clinically challenging cases.
3. Pelvis hardware.
4. Bariatric patients

Protocols needing modification from this review:

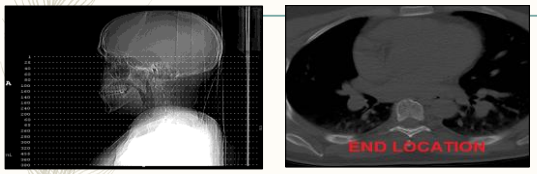
1. CT1Y6 - cap the mA on the CTA head and neck at 550 mA
2. Increase notification level to 45 mGy on the Myelograms wo hardware and 60 mGy with hardware
3. Pelvis hardware (CT4B2, CT1W1, CT1WA AND CT1NS) - Change the Rotation Time to 0.6 seconds

Dose Notification for Head CT

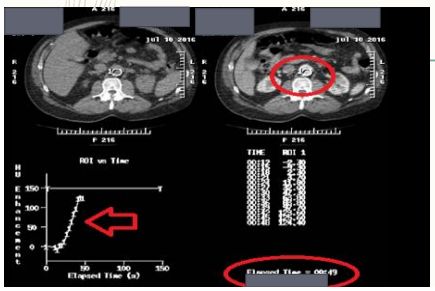
	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGycm	Ti s	cSL mm
Patient Position F-BP							
Topogram	1	120	35 mA	0.13 L	12.7	9.5	0.6
Topogram	2	120	35 mA	0.13 L	13.2	9.8	0.6
Contrast							
CHEST	3	100	98 /134	3.89 L	154.3	0.5	0.6
CA ABD/PEL	4	100	161 /275	8.35 L	308.1	0.5	0.6
Contrast							
I+ BRAIN	5	120	501 /315	83.69 S	1837.4	1.0	0.8



Cervical Spine (CTDI vol 36 mGy)?



Too long cervical spine CT
Large patient with large shoulders
Dose modulation or AEC



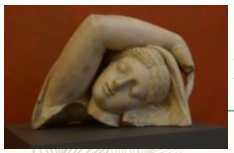
CTDIvol 68 mGy

Too early start:
12 sec
Too long continued:
49 seconds

CT Dose Monitoring

– Physics & CT QC teams: Quarterly Dose Review

Date	Scanner	CTDIvol	DLP	Comments	Action
6/1/2016	CT2W1	99.0	1969.5	Siemens Softerware Glitch	Education/ Ensure to have lateral topogram without cutoff
6/5/2016	CT2W1	95.1	2005.7	Bariatric patients	N/A
6/7/2016	CT2W1	109.4	3617.8	Large shoulders in the topogram	Consider to use fixed technique for head
6/9/2016	CT1Y6	105.4	1024.6		Further review.
6/13/2016	CT2B2	95.1	1785.0	Used fixed technique	Should use AEC
6/13/2016	CT1NS	83.6	3613.1	Fixed technique too high	Lower the fixed technique
6/14/2016	CT2W1	94.6	2023.2	Large shoulders in the topogram	Consider to use fixed technique for head
6/16/2016	CT1WA2	89.0	3686.2	Tabletop head, scout with arms, AEC	Should used fixed technique, Education
6/18/2016	CT2W1	115.1	3851.8	Patient moved after topogram	Education/ retopo after patient being moved
7/26/2016	CT1NS	80.9	3497.7	Feet first technique too high	Consider to use fixed technique for tabletop feet first head
8/13/2016	PETCT1L6	89.1	3083.0	Used AEC	Should use fixed technique
8/13/2016	CT1W1	101.8	3411.2		Further review of protocol
8/19/2016	CT2W1	92.5	1877.3	Siemens Softerware Glitch	Education/ Ensure to have lateral topogram without cutoff
8/20/2016	CT2W1	84.7	1600.3	Large shoulders in the topogram	Consider to use fixed technique for head
8/21/2016	CT2W1	99.4	1747.6	Siemens Softerware Glitch	Education/ Ensure to have lateral topogram without cutoff



Lessons on Managing Dose

- Continuous dose monitoring while maintaining quality
- Tailoring radiation dose to clinical indication
- Adapting doses to patient body habitus
- CT radiation dose will exceed the notification values and certainly can be higher than DRLs

Reference: Kalra MK et al. CT Radiation: Key Concepts for Gentle and Wise Use. Radiographics. 2015 Oct;35(6):1706-21.

Summary from MGH Dose Tracking

- **Boss is always right**
  - Medical physicists better at tracking than MD
    - Dose tracking and optimization are dynamic and ongoing
- **Teamwork is a must**
  - Team work: Medical Physicist (lead), CT RTR, Radiologists
- **Dose tracking is the right thing to do**
  - Helps identify issues
  - Helps fix issues (some)
  - Not all problems are fixable! !

Acknowledgement

- Medical Physicists at MGH
  - Bob Liu, PhD; Kai Yang , PhD; Matthew Delorenzo , PhD
- CT technologists at MGH
  - Cristy Savage, CT QA manager
- CT protocols in-charge radiologists