

*2nd AAPM Summit on CT Dose:  
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# Imaging Physician's Role In CT Protocol Design And Review

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# Role of Imaging physician:

## Outline

- Assign radiologist and technologist
- Determining appropriateness of indication for CT
- Designing indication driven scan protocols
- Implementation on CT scanners
- Periodic review of scan parameters: QatchAll

# Assign Responsibility: The MGH way

- Radiologist
  - One subspecialty radiologist responsible for their section CT
    - Makes protocols with or without help from.....
    - Shares with Division head (depends) or others (variable)
    - Relays to the CT technologist supervisor
    - Monitors trial run and quality
    - Listens to complaints
- Supervisor Technologist
  - May or may not participate in making protocols
  - Responsible for saving, printing and installing protocols
  - Listens from the Radiologists for issues

# Establishing appropriateness

- First step to all dose reduction
- Review indications for CT
  - External guidelines: Ex: ACR appropriateness criteria
  - Internal dialogue:
    - Amongst subspecialty radiologists
    - Key referring physician
  - Automating Radiology exam ordering: ROE
  - Simplifying process of selecting appropriate exam order:  
Decision support

# Justification of scanning indications

MGH Radiology Order Entry - Microsoft Internet Explorer provided by Partners HealthCare System

Save Exam

Print Form

Exit Exam

At least one box **MUST** be selected from either of the following groups

## SIGNS / SYMPTOMS

- |   |   |
|---|---|
| <input type="checkbox"/> Back pain                          | <input type="checkbox"/> Chest pain acute, cardiac origin   |
| <input type="checkbox"/> Chest pain acute, pulmonary origin | <input type="checkbox"/> Chest pain chronic, cardiac origin |
| <input type="checkbox"/> Chest pain, normal EKG             | <input type="checkbox"/> Chest wall pain                    |
| <input checked="" type="checkbox"/> Cough (persistent)      | <input type="checkbox"/> Fatigue and malaise                |
| <input type="checkbox"/> Fever                              | <input type="checkbox"/> Hemoptysis                         |
| <input type="checkbox"/> Lymphadenopathy                    | <input type="checkbox"/> Night sweats                       |
| <input type="checkbox"/> Rales                              | <input type="checkbox"/> Shortness of breath                |
| <input type="checkbox"/> Mass or lump on chest or back      | <input type="checkbox"/> Weight loss                        |

## KNOWN DIAGNOSES (NOT Rule/out!)

- |  |   |
|--|---|
| <input type="checkbox"/> Aortic dissection                   | <input type="checkbox"/> Pericardial effusion/abnormality |
| <input type="checkbox"/> Bronchiectasis                      | <input type="checkbox"/> Emphysema                        |
| <input type="checkbox"/> Congenital heart disease            | <input type="checkbox"/> Interstitial lung disease        |
| <input type="checkbox"/> Injury to trunk                     | <input type="checkbox"/> Metastatic disease               |
| <input type="checkbox"/> Interstitial Lung Disease (Chronic) | <input type="checkbox"/> Neoplasm - Lung cancer           |
| <input type="checkbox"/> Neoplasm - Lung cancer              | <input type="checkbox"/> Neoplasm - Mesothelioma          |
| <input type="checkbox"/> Neoplasm - Mesothelioma             | <input type="checkbox"/> Neoplasm - Primary Unknown       |
| <input type="checkbox"/> Neoplasm - Primary Unknown          | <input type="checkbox"/> Pneumothorax                     |
| <input type="checkbox"/> Pneumothorax                        | <input type="checkbox"/> Pulmonary Hypertension           |
| <input type="checkbox"/> Pulmonary Hypertension              | <input type="checkbox"/> Transplant rejection             |

**Chest CT is indicated for the clinical indications provided**



**Alternate procedures to consider:**

X-Ray  
9

### Options:

- [Proceed](#) with exam
- [Cancel](#) or select new exam
- [Change](#) indications and resubmit



# Avoid Unintentional Repeats & INFORM

MGH Radiology Order Entry - Microsoft Internet Explorer provided by Partners HealthCare System

Patient Name:

Proceed



## RADIATION ALERT!

The patient had 1 (Click the number to view) previous CT scans at Partners Imaging Centers.

[How to interpret this result](#)

Click 'Proceed' to proceed to order the exam or 'Cancel Exam' to cancel the exam:

Exposure to X Rays may increase the risk of developing cancer. The risk is difficult to quantify (see links below for more information). Radiation-related cancers are delayed following exposure, often by many years, and therefore this risk may not be clinically important for elderly patients or those with critical illness. Children are more sensitive to radiation, and have on average longer life expectancy after exposure, so are at higher risk than adults.

Organs vary in their sensitivity. Exposure to one organ does not affect the cancer risk FOR other organs. The cancer risk is related to the cumulative dose and the amount of exposed tissue. There is no safe "threshold" below which there is no risk.

Although it is possible that several hundred cancer deaths may occur each year in the US due to exposure from CT scans,, this number is a tiny fracture of total cancer deaths. The risks of radiation-induced cancer must be balanced against health benefits of the scan.

Risks from radiation exposure can be limited by:

- 1) Performing CT scans only when essential
  - ROE Decision Support can help you make an informed judgment about exam appropriateness
- 2) Limiting the exposed area to the minimum required for diagnosis
- 3) Performing studies with the lowest dose achievable.
  - MGH and Partners radiology departments use protocols to minimize the exposed field and use the lowest effective amount of radiation

n (Site)

Scheduled Date

[W/Con W 3D \(MGH\)](#)

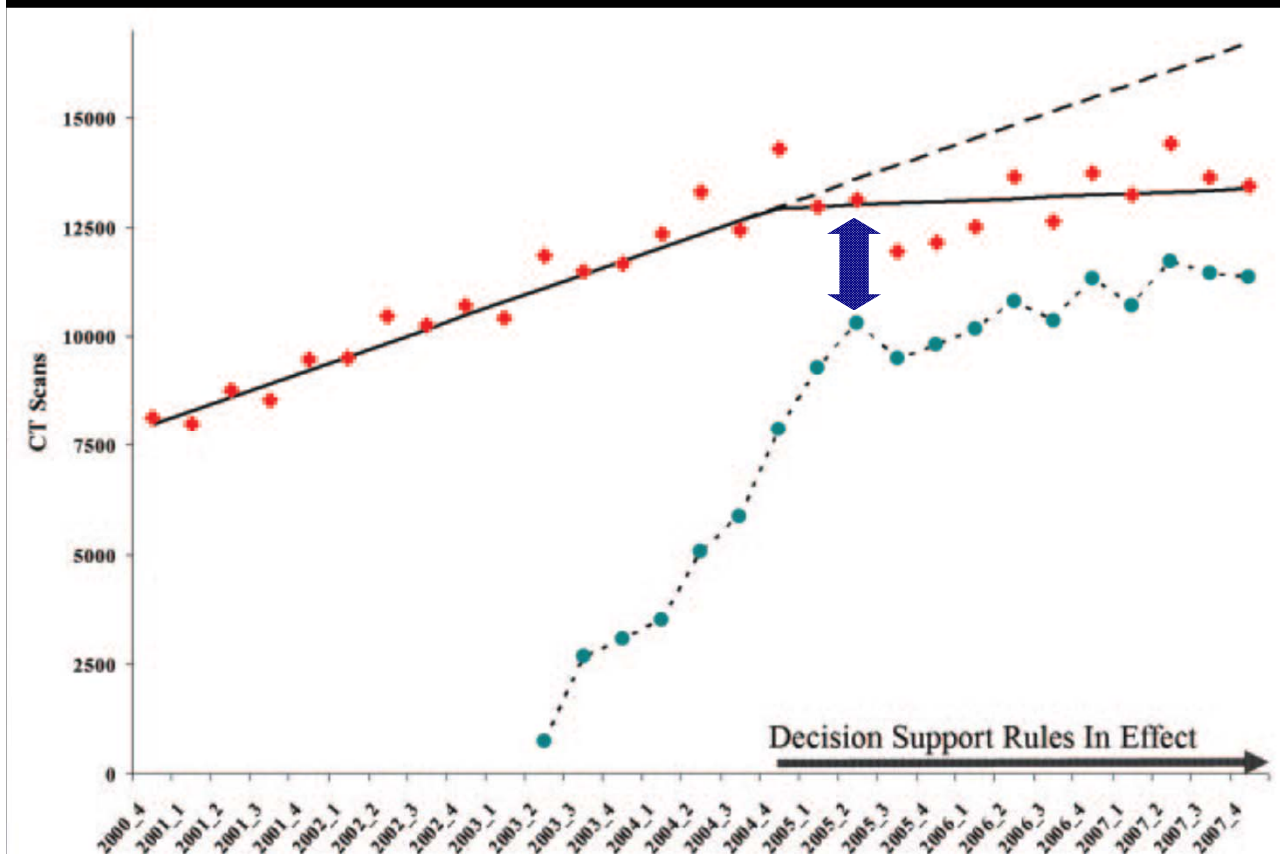
07/27/2008

Click 'Proceed' to proceed to order the exam or 'Cancel Exam'

OK

Cancel Exam

# Justified CT: Effect on volume



Appropriateness for CT is not an optional scan factor.

Decision support and practice guidelines help.



# Know the CT Inventory

- Scanner vendors
  - Company that made the CT
- Scanner types:
  - Number of detector rows for MDCT
  - Number of x-ray sources
- Reconstruction options on individual scanners:
  - FBP
  - FBP and partial IRT

# Steps to Design Protocol

- For each scanner:
  - Separate protocols for different body regions
  - In each body region:
    - Start always from indications
  - Next optimize scan parameters for patient size
  - Always separate adult and pediatric CT
  - Start designing from the “routine” or “general” protocol
  - Migrate to specific higher or lower dose protocols

# Clinical indications: Image Quality

- Requirement of image quality and dose is specific to the clinical indication
- Tailoring CT protocols to clinical indications is therefore important

# Region

- Subspecialist or generalist or technologist
- Important to make & save Head protocol in head section and not in body section
  - Eg. Siemens
    - specific kernel for head and body
    - Dose specific to head with 16 cm phantom
  - Eg. GE
    - Dose specific to head with 16 cm phantom
- Likewise, save and archive pediatric protocols in pediatric page or section on CT console

## In each region: Indication driven protocols

Protocol	Clinical Reasons	Specific instructions
Routine chest with IV contrast	Lung masses, infections, assessing mediastinum/ hilum/ pleura, chest wall mass, trauma	Rules for prone series
Routine chest without contrast	Elevated creatinine for above, Follow-up pulmonary nodule	Rules for prone series
Diffuse lung disease protocol	e.g. Sarcoid, bronchiolitis obliterans, asthma, COPD, ILD, pulmonary fibrosis	+ Expiratory & Prone images
Lung nodule follow up	Lung nodule on prior CT	Do not cover beyond lungs (no adrenals)
Lung cancer screening	Lung cancer screening in high risk patients	Do not cover beyond lungs (no adrenals)
CT PE	Suspected or known pulmonary embolism	Apices to lung bases (no adrenal coverage)
Tracheal protocol	Tracheobronchomalacia Tracheal stenosis	+ Inspiratory & expiratory (MPR, virtual Bronchoscopy)

# Tailoring Dose to indications

Study	Year	Indications	No. of Patients	Standard Current–Time Product (mAs)	Reduced Current–Time Product (mAs)	Peak Kilovoltage (kVp)	Smallest Acceptable mAs
<u>Follow-up of malignant disease</u>							
Chiu et al. [56]	2003	Lung cancer	30	240	43	120/140 (standard/reduced)	43
Dinkel et al. [29]	2003	Lymphoma and extrathoracic malignancy	40	150	15	120	15
Yamada et al. [30]	2004		20	96	45	140	45
<u>Bronchiectasis</u>							
Jung et al. [60]	2000		52	170 (1 mm thick)	40 (2 mm thick)	120	40
Yi et al. [61]	2003		20	170 <sup>a</sup>	70 <sup>a</sup>	120	70
<u>Emphysema</u>							
Zompatori et al. [58]	2002		18	48	192	120	48
Zaporozhan et al. [59]	2006		30	150	10–100 <sup>b</sup>	120	30–50
<u>Other indications</u>							
Remy-Jardin et al. [57]	2004	Asbestosis	83	60–100 (1 mm thick)	60–100 (5 mm thick)	140/120 (standard/reduced)	60–100
Coppenrath et al. [33]	2004	Follow-up of nonmalignant disease	41	170	80	140	80
Tack et al. [54]	2005	Pulmonary emboli	21	157.5 <sup>c</sup>	17.5–105 <sup>d</sup>	120	17.5



# Specific parameters: kVp and mA

- What kVp should be used
  - Higher kVp: routine CT, abdomen
  - Lower KVp: CTA, perfusion
  - Manual versus automatic KVp selection: CarekV, Siemens
- Tube current
  - Most body CT and even head CT: Use AEC
  - AEC adapts for body size and region
  - Radiologist adapts AEC to clinical indications

# Other players

- Pitch:
  - Head CT: Close to 0.5 or 0.6
  - Body CT: Set per requirement of scanning speed ( $\geq 1$ )
  - Fast scanning: Flash DSCT pitch can go much higher ( $>1.5$ )
- Detector configuration:
  - Bigger is better ( $16 * 1.25$  is better than  $16 * 0.625\text{mm}$ )
  - Caveats: head or higher res (Siemens :  $12 * 0.3\text{mm} > 64 * 0.6\text{mm}$ )
- Slice thickness: Acquire thins, reconstruct thick: Less noise
- Number of scan phases: Abdomen routine non contrast eliminated
- Scan coverage: scan length
- Rotation speed: Keep fastest...for most regions

# Tailoring Indications For Patient Size

Patient weight	FBP CT (64,16, 8 -CT)	ASiR CT (GE HDCT)	Young patients (<40 years)	Lung nodules (fixed mA)
<135 lbs	25 NI (75 - 250 mA)	32 NI (75 - 200 mA)	30 NI (50 -150 mA)	30 mAs
135-200 lbs	30 NI (75 - 350 mA)	35 NI (75 - 250 mA)	30 NI (50-200 mA)	60 mAs
>200 lbs	30 NI (75 - 550 mA)	38 NI (75 - 350 mA)	35 NI (75 - 350 mA)	90 mAs
	AEC	AEC	AEC	No AEC

2.5 mm section thickness  
Protocol for GE MDCT with Auto mA 3D

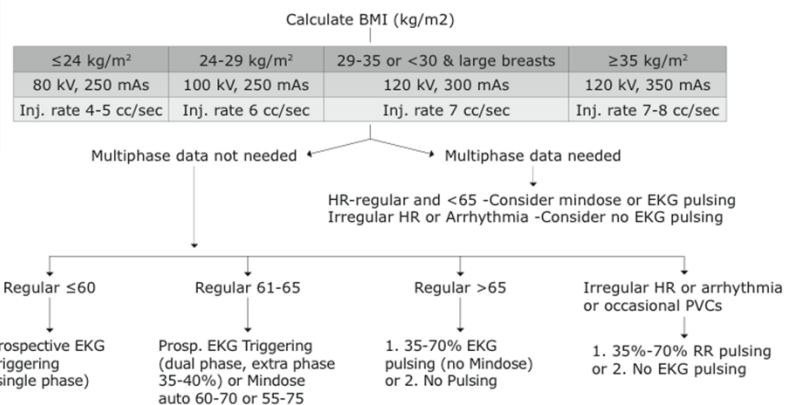
CHEST		CT PROTOCOL 64 SLICE GE Scanner			RETRO RECON	
Feb-08					Thickness:	1.25 mm
<b>CHEST</b>					Interval:	0.625 mm
<b>SERIES 1: SCOUTS- SEND TO PACS AS SERIES 1</b>					Algorithm:	ASIR 30 STD
Landmark		SN			DFOV:	Skin - Skin
Scout		AP and LAT			Recon Mode:	RETRO (NOT PROSP)
Technique		80 kV 20mA			Send to PACS?	<b>NO</b>
<b>SERIES 2: CHEST I+</b>					LUNG HRCT RETRO	
Location		Technique			Thickness:	1.25mm
Mode		<b>SERIES 4: DELAYED PRONE (if pleural fluid) SEND</b>				
Time		Location				Limit to area of effusion
Thickness		Mode				Helical
Detector		Time				0.5
Pitch		Thickness				7.5 mm
Speed		Pitch				1.375
Interval		Speed				55 mm / rotation
Gantry Tilt		Interval				7.5 mm (limit to area of effusion)
SFOV		Gantry Tilt				0
KV		SFOV				Large
Auto MA		KV				100
Noise Index		Fixed mA				100
DFOV		Noise Index				Do not use Auto mA
ALG	ASIR	DFOV				skin to skin
<b>SERIES 3: PR</b>		API				Inspiration
Landmark:		ALG				Standard
Scout:						
Technique						

# Cardiac CT

## CLASS I

- Age <40 years
- No Calcium
- Minimal/small calcium plaques (Ca score ≤10)
- Non coronary indications for CT (e.g. congenital heart disease, anomalous coronary artery, cardiac tumors, pulmonary veins).

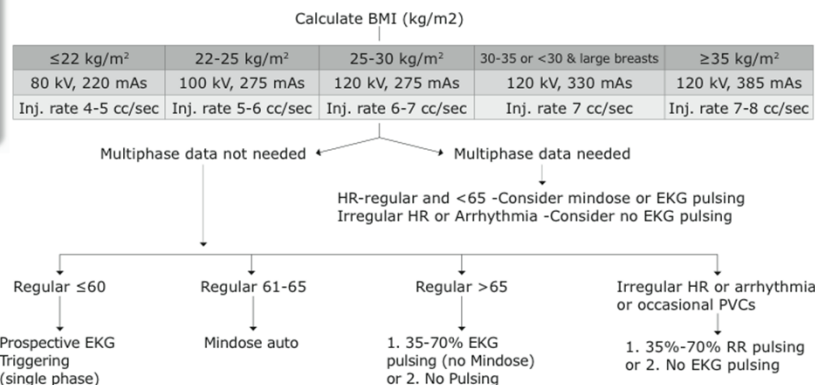
Use CareDose 4D



## CLASS II

- For assessing suspected or known coronary artery disease
- Some calcium/Scattered plaque
- Ca score of 11-99 on previous CT (within one year) or present CT

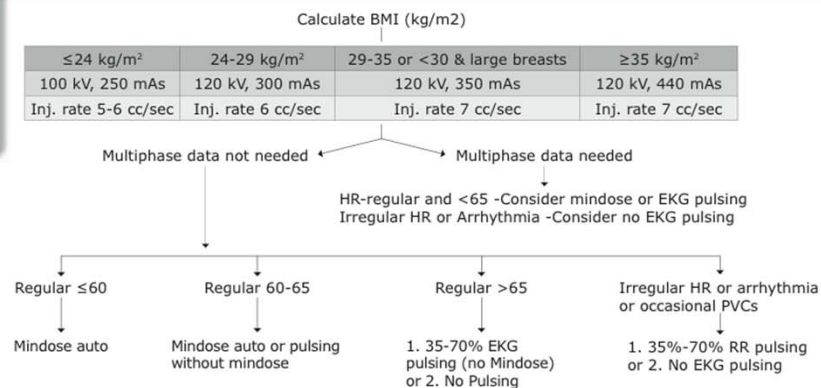
Use CareDose 4D



## CLASS III

- Patients >70 years with any indication for scan (don't over kill the dose)
- Post- CABG
- Post- coronary stent placement
- Ca score ≥100 on any CT
- Heavy calcified plaques in the coronaries

Use CareDose 4D



## General Guidelines

- For Pediatric patients,
  1. ALWAYS consult with attending a day before the scan.
  2. Injection rates and ROI need to be discussed with the attending.
  3. For BMI < 30 kg/m<sup>2</sup>, use 80 kV.
  4. For BMI > 30 kg/m<sup>2</sup>, use 100-120 kV.
  5. When assessment of coronary arteries or small intracardiac lesions or is not indicated, consider non-gated CT. (eg: pulmonary arteries, Coarctation, Extracardiac shunt)
- Strongly consider beta blocking to get to ≤60 bpm to enable lower dose scanning unless contraindicated.
- Remember these are guidelines, if you have a valid reason you can and should use your own judgment.
- Refer to ResHub for contrast safety guidelines.

# Pediatric Body CT

## FOR MOST ROUTINE INDICATIONS / "RULE OUT" SITUATIONS

Pink Zone 1		Weight	CARE Dose 4D (Reference mAs)	KVP
	BABIES	< 20 lb	60	80
	CUTIES	21-60	60	100
	KIDDIES	61-100	60	120
	TEENIES	101-200		
	BIGGIES	> 201		

SIEMENS CT SCANNERS  
patients 18 years old and less

**PEDIATRIC** CT zones

## REMINDERS TO ALL CT TECHNOLOGISTS

1. Use **YELLOW** for all Pediatric Stone Protocol CT
2. Use **GREY** for all Pediatric CT Angiography

3. If you are still not clear and you cannot ask, use **PINK**
4. Weight whenever possible, guess when not possible but always **DOCUMENT** the weight.

Green Zone 2		Weight		
	BABIES	< 20 lb		
	CUTIES	21-60		
	KIDDIES	61-100		
	TEENIES	101-200		
	BIGGIES	> 201	135	120

## ULTRA-LOW DOSE CT (BONES/MULTIPLE PRIOR CT)

Red Zone 3		Weight	CARE Dose 4D (Reference mAs)	KVP
	BABIES	< 20 lb	35	80
	CUTIES	21-60	35	100
	KIDDIES	61-100	35	100
	TEENIES	101-200	70	120
	BIGGIES	> 201	120	120

## STONE PROTOCOL

Yellow Zone 4		Weight	CARE Dose 4D (Reference mAs)	KVP
	BABIES	< 20 lb	40	80
	CUTIES	21-60	40	100
	KIDDIES	61-100	40	120
	TEENIES	101-200	80	120
	BIGGIES	> 201	130	120

## HIGH DOSE/HIGH RESOLUTION CT (SUBTLE/SMALL LESIONS)

Blue Zone 5		Weight	
	BABIES	< 20 lb	
	CUTIES	21-60	
	KIDDIES	61-100	
	TEENIES	101-200	
	BIGGIES	> 201	

## RADIOLOGIST Help us help our kids by adhering to these Protocols

### 1. Prescribe **YELLOW** for all Pediatric Stone Protocol CT

### 2. Prescribe **GREY** for all Pediatric CT Angiography

3. CT dose is cumulative so we **STRONGLY ENCOURAGE** you to employ **GREEN** for follow-up of benign, non-cancer lesion (Ex. follow-up of pneumonia, abscess, pancreatitis, pleural effusion, kidney stones)

4. CT primarily for bones (deformities, scoliosis, fractures) or in patients with multiple studies for same indication **MAY BE** performed with **RED** zone. You may further cut the dose by specifying the region to be scanned (e.g. liver, pelvis)

5. If quality is not acceptable, contact Dr. Westra or Dr. Kalra

Grey Zone 6		Weight	CARE Dose 4D (Reference mAs)	KVP
	BABIES	< 20 lb	60	80
	CUTIES	21-60	60	100
	KIDDIES	61-100	60	100
	TEENIES	101-200	120	120
	BIGGIES	> 201	160	120

2.5 mm section



# Converting to IRT

## Pediatric Body CT

**1<sup>st</sup> Recon : ASIR 50% - 5 mm**  
50% lower dose comp. to FBP

PINK ZONE					
	Weight	Noise Index	Minimum mA	Maximum mA	kVp
BABIES	<20 lbs	5	65	130	80
CUTIES	20-60	8	80	160	100
KIDDIES	60-100	11	95	190	120
TEENIES	100-200	13	110	220	120
BIGGIES	>200	15	130	300	120

	Weight	Noise Index	Minimum mA	Maximum mA	kVp
BABIES	<20 lb	7	40	80	80
CUTIES	21-60	10	50	100	100
KIDDIES	61-100	14	60	120	120
TEENIES	100-200	17	70	140	120
BIGGIES	>200	18	100	240	120

# Adapting to Siemens Equipment: Pediatrics

<b>GREEN ZONE</b>	Weight	Quality Ref mAs:	KVP
Babies	<20 lbs	50	80
Kiddies	20-80 lbs	50	100
Teenies and biggies	>81 lbs to any weight	100	120
<b>PINK ZONE</b>	Weight	Quality Ref mAs:	KVP
Babies	<20 lbs	80	80
Kiddies	20-80 lbs	80	100
Teenies and biggies	>81 lbs to any weight	150	120
<b>RED ZONE</b>	Weight	Quality Ref mAs:	KVP
Babies	<20 lbs	36	80
Kiddies	20-80 lbs	36	100
Teenies and biggies	>81 lbs to any weight	80	120

# Sharing protocol files

- Once protocols are made
  - Educating the CT technologists
  - Saving CT protocols on individual scanners
  - Ensuring protocols for head go to head section only
  - Trial run in few cases – Review of images-
    - Full throttle
    - Tweak and re-trial and re-review images
  - Locked in protocols: Avoid unintended changes

# Sharing protocol files

- Having hard copy protocol books by body region in all scanner suites
  - Scan length
  - Scan phases or passes
  - Contrast injection details
- Shared drive access to protocols with in the intranet from any internal personal computer
  - Electronic copies of protocols with version date and protocol types

Name ▲	Size	Type	Date Modified
GE 16 PROTOCOLS		File Folder	8/24/2011 8:23 AM
GE 64 HD PROTOCOLS		File Folder	8/24/2011 8:22 AM
GE 64 Protocols		File Folder	8/24/2011 8:20 AM
SIEMENS 64 PROTOCOLS		File Folder	8/24/2011 8:19 AM
SIEMENS 128 FLASH PROTOC...		File Folder	8/24/2011 8:20 AM

2011\Protocol\GE 64 HD PROTOCOLS

Name ▲	Size	Type	Date Modified
Abdomen Protocols		File Folder	8/24/2011 8:23 AM
Chest protocols		File Folder	8/24/2011 8:23 AM
Neuro Protocols		File Folder	8/24/2011 8:22 AM

2011\Protocol\GE 64 HD PROTOCOLS\Chest protocols

Name ▲	Size	Type	Date Modified
old protocols		File Folder	8/24/2011 8:23 AM
CH-ABD-PEL_ART-PV over 300 lbs_HDGE...	50 KB	Microsoft Office Exc...	12/9/2010 5:00 PM
CH-ABD-PEL_ART-PV under 300 lbs_HDG...	52 KB	Microsoft Office Exc...	11/30/2010 11:53 AM
Chest Abd Pelvis over 300 lbs_HDGE64_1...	47 KB	Microsoft Office Exc...	11/30/2010 11:41 AM
Chest Abd Pelvis under 300lbs_HDGE64_1...	49 KB	Microsoft Office Exc...	11/30/2010 11:38 AM
Chest_and_ Neck_HDGE64_11-2010	88 KB	Microsoft Office Exc...	11/24/2010 9:39 AM
CTPE ALL HDCT64_1.25.10	352 KB	Microsoft Office Exc...	3/1/2010 3:14 PM
CTPE_GSI_HDGE64_ 3.23.10	343 KB	Microsoft Office Exc...	11/9/2010 1:39 PM
DIFFUSE LUNG DISEASE_HDGE64_11-2010	73 KB	Microsoft Office Exc...	12/2/2010 4:21 PM
Neck Chest Abd Pelvis over 300 lbsHDGE...	113 KB	Microsoft Office Exc...	11/30/2010 1:18 PM
Neck Chest Abd Pelvis ART-PV over 300 l...	52 KB	Microsoft Office Exc...	11/30/2010 1:19 PM
Neck Chest Abd Pelvis ART-PV under 300l...	78 KB	Microsoft Office Exc...	11/23/2010 4:18 PM
Neck Chest Abd Pelvis under 300 lbs_HD...	115 KB	Microsoft Office Exc...	11/30/2010 12:34 PM
ROUTINE NECK _HDGE10-2010	584 KB	Microsoft Office Exc...	11/23/2010 3:41 PM
Superdimension Branch_HDGE64_2.2.10	74 KB	Microsoft Office Exc...	3/1/2010 4:04 PM
Thoracic Chest Wall3D_HDGE64_2.2.10	74 KB	Microsoft Office Exc...	3/1/2010 4:10 PM
Tracheal Protocol ALL_HDGE64_2.2.10	54 KB	Microsoft Office Exc...	3/1/2010 4:13 PM
Virtual Branch ALL_HDGE64_2.2.10	52 KB	Microsoft Office Exc...	3/1/2010 4:19 PM

# MGH- Auditing doses with CT

Body regions	NCRP-160		Arch. Intern. Med: 2009*		MGH-2010	
	Mean Eff. dose (mSv)	Range Eff. dose (mSv)	Mean Eff. dose (mSv)	Range Eff. dose (mSv)	Mean Eff. dose (mSv)	Range Eff. dose (mSv)
Abdomen	10	3-25	12	-	<b>6.9</b>	<b>3-11.2</b>
Chest	7	4-18	7	-	<b>3.2</b>	<b>1.9-6.2</b>
Neck	-	-	-	-	<b>3.3</b>	<b>1.4-14.8</b>
Head	2	0.9-4	2	-	<b>2.0</b>	<b>1.9-2.4</b>
CTA head	5	1-10	5	-	<b>4.5</b>	<b>2.7-5.6</b>
CTA Heart	20	5-32	-	-	7.6 retrospective	3-15.6
					1.9 prospective	0.6-4.3



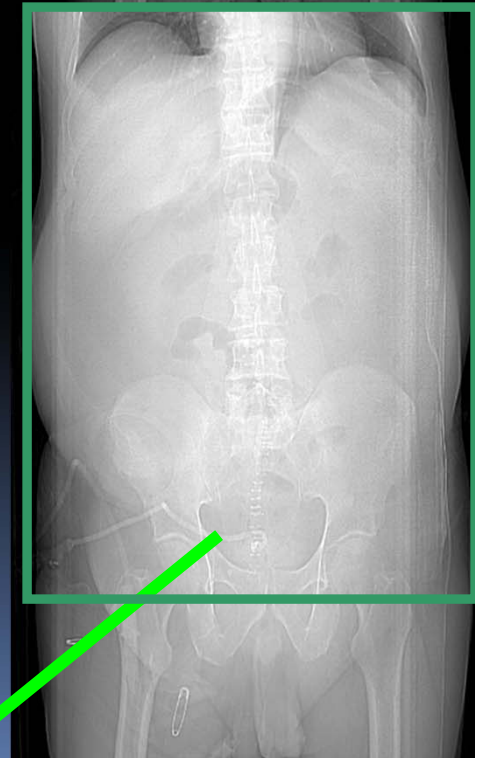
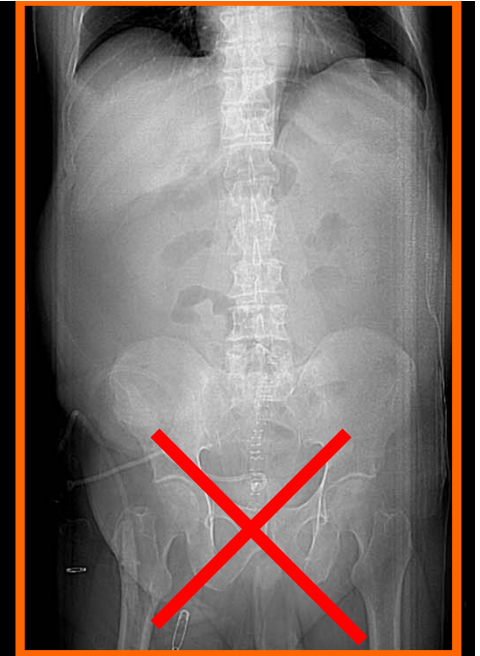
# Monitoring for Dose Compliance

- Scan range
- Scan overlap
- CT procedure
- Axial versus helical use
- Position of arms for localizers and AEC

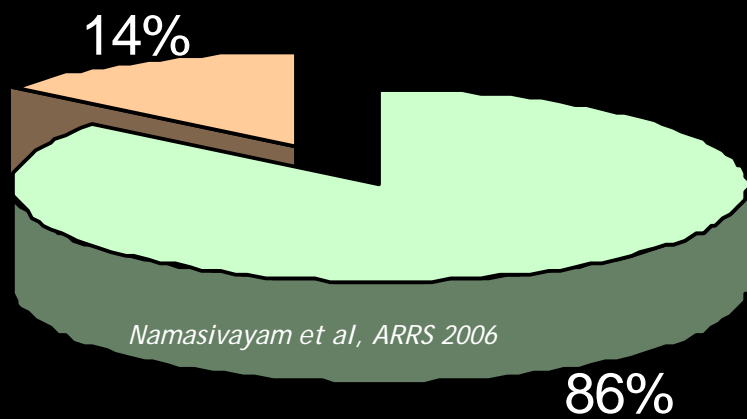
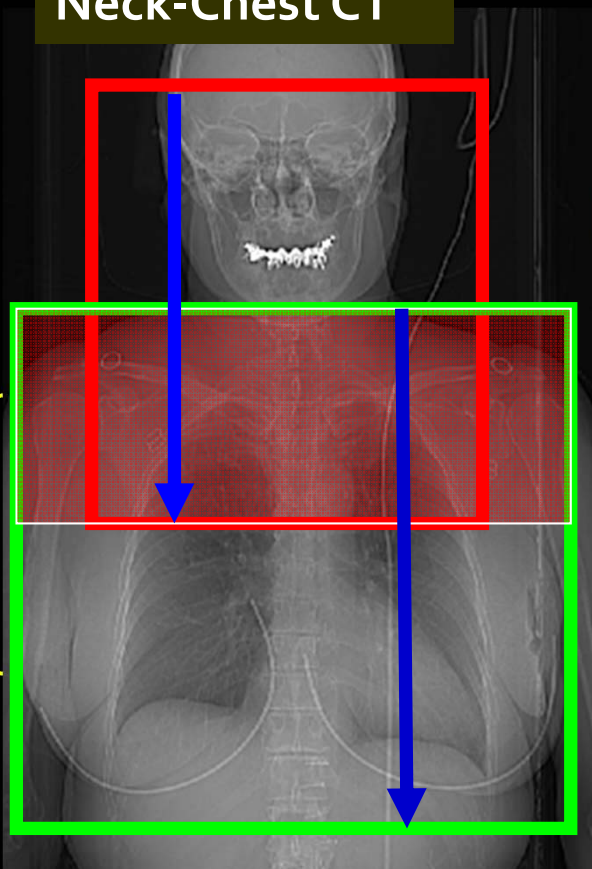
# Scan length

- 95% of CT abdomen have extra images acquired beyond the area of interest.
- Study showed that 1280 extra images were acquired in 106 patients equivalent to that in 12 -16 CT exams!
- Limit scan to intended anatomic area to cut dose by 10%
  - Abdomen:
    - Just above diaphragm – Inferior pubic symphysis
  - Chest:
    - Routine: Apex to adrenals
    - PE or benign clinical reasons: Apex to lung bases

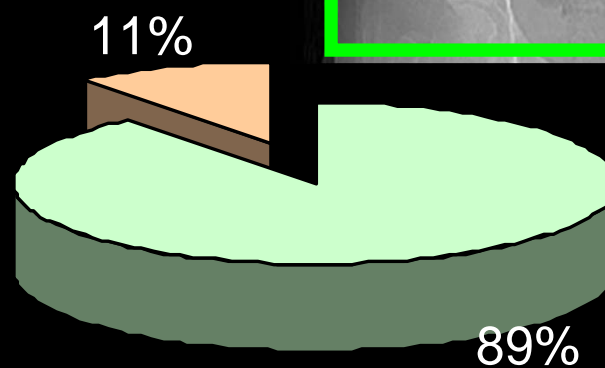
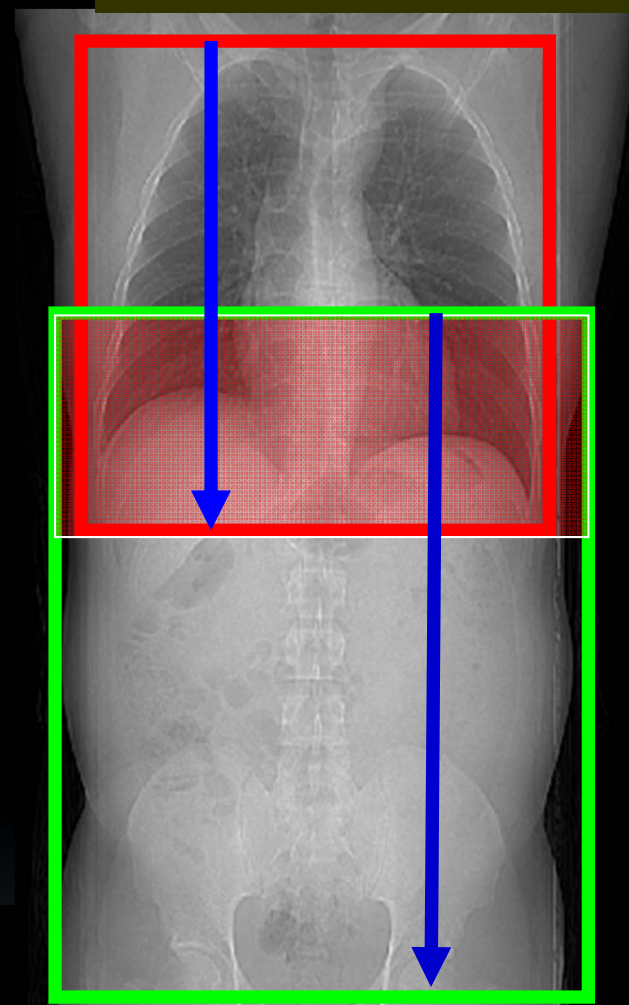
*Namasivayam et al, ARRS 2006*



## Neck-Chest CT



## Chest-Abdomen CT



# Position of arms for neck-chest CT

20 mGy



14 mGy



20 sec later with  
no change in scan factors

Kalra et al. AJR 2004

# Conclusion

- Imaging physician plays an important role in
  - Making justification for certain clinical indication
  - Indication driven protocols
  - Patient size based dose optimization
  - Education of technologists
  - Archiving protocols online & in accessible paper files
  - Monitoring compliance with protocols

# Acknowledgement

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- Priyanka Prakash, MD