Dosimetry and Common Pitfalls in the ACR CT Accreditation Program

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Outline

- Dosimetry
- Pitfalls

Dosimetry

- **Clinical** Adult Head
- **Clinical** Adult Abdomen
- **Clinical** Pediatric Abdomen **(40 lb, 20 kg)**
- Must measure dose in **axial mode**
- **Table 1**
- FDA phantoms
  - 16 cm head
  - 32 cm body
  - Non-chamber holes must be filled
  - For Pediatric Abdomen, must use head phantom on table

Axial Conversion

- Note actual z-axis (detector) collimation (T) and number of data channels (N) used
- Do not confuse z-axis collimation with nominal slice thickness!
- May not be able to achieve the same detector configuration in axial as used in helical

Axial Conversion

- Determine NT of detector configuration underlying the clinical helical protocol
- **Select axial detector configuration most closely matching the helical NT**
- Use this axial detector configuration in all subsequent calculations
- Adjust table speed in calculation to keep **pitch** the same

Particularly Pesky Scanner?

- Call or e-mail the ACR
  - Might be able to answer question directly
  - Might e-mail the physics subcommittee

Axial Conversion

- Example: Siemens Sensation 16
  - N = 16, T = 1.5 mm ⇒ NT = 24 mm
  - Pitch = 1.2
  - Reconstructed scan width = 5 mm
  - Cannot get axial images N = 16

So…
- Use T = 1.5 mm, N = 12 ⇒ NT = 18 mm
- Table speed = 21.6 mm in calculation

Pitch

- Must use IEC definition
  - Pitch = I/N*T
    - I = table increment/speed
    - N = number of data channels used
    - T = z-axis collimation
  - Not always stated correctly on the CT system
- Why?
  - Still used improperly
  - Confusion of relationship between NT, I and recon. scan width and increment

Dosimetry Calculations

- CTDI at central axis and periphery

$$CTDI_{100} = f \bullet C \bullet E \bullet L / (N \bullet T)$$

where

f = 0.87 rad/R
C = electrometer/chamber correction factor
E = measured exposure
L = active chamber length
N = number of data channels
T = z-axis collimation

Dosimetry Calculations

- $CTDI_W$ = weighted axis and periphery

$$CTDI_W = 1/3\ CTDI_{axis} + 2/3\ CTDI_{periph}$$

- $CTDI_{vol}$ = CTDIw/pitch

	Head	Ped Abd	Adult Abd
Reference	75	20	25
Maximum (**Pass/Fail**)	80	25	30

Head Doses

- NOTE: Increased head reference dose does not mean that you SHOULD increase dose
  - New values based on experience through CTAP
  - A number of scanners could not achieve acceptable image quality at original value
  - MANY SCANNERS COULD
  - If images were acceptable at 60 mGy limit, leave it

Dosimetry Calculations

$$CTDI_{VOL} = CTDI_W * N * T / I \quad \text{(axial)}$$
$$= CTDI_W / \text{pitch} \quad \text{(helical)}$$

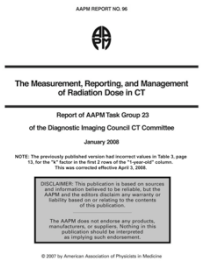
$CTDI_W$		N	T	I	Pitch	$CTDI_{VOL}$	
58	Pass	4	5	20	--	58	Pass
58	Pass	4	5	10	--	116	FAIL
24	Pass	--	--	--	1	24	Pass
27	Pass	--	--	--	0.75	36	FAIL
38	FAIL	--	--	--	1.5	25	Pass

Dosimetry Calculations

- DLP (mGy-cm) = $CTDI_{VOL}$ (mGy) • total scan length (cm)
  - For ACR, assume total scan length = 17.5 cm for head
    = 25.0 cm for adult abd.
    = 15.0 cm for ped. Abd.
- Effective Dose (E) = k (mSv/mGy-cm) * DLP (mGy-cm)
  - **Where k = 0.0021 for head**
    = 0.015 for adult abd.
    = 0.020 for ped. abd.
- Must use appropriate spreadsheet

New Conversion Factors

- AAPM Report 96
- Monte Carlo modelling
- More accurate dose calculation
- Values
  - Head: k=0.0021
  - Adult Abd.: k=0.015
  - Ped. Abd.: k=0.020


AAPM REPORT NO. 96

The Measurement, Reporting, and Management of Radiation Dose in CT

Report of AAPM Task Group 23
of the Diagnostic Imaging Council CT Committee

January 2008

NOTE: The previously published version had incorrect values in Table 3, page 13, for the "k" factor in the first 2 rows of the "1-year-old" column. This was corrected effective April 3, 2008.

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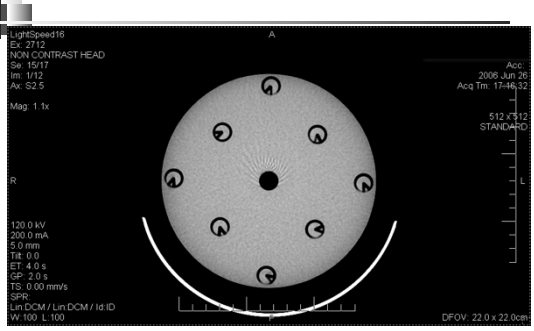
New Conversion Factors

- Download new Phantom Dose Calculator Spreadsheets
  - http://www.acr.org/accreditation/computed/qc_forms.aspx
- Modify your own

27	CTDIw (mGy)		#DIV/0!
28	**Clinical exam dose estimates** (using measured CTDIw and site's Adult Abdomen Protocol from Table 1)		
29	CTDIvol (mGy)	=CTDIw*N*T/I	#DIV/0!
30	DLP (mGy-cm)	=CTDIvol*25	#DIV/0!
31	Eff Dose (mSv)	=DLP*0.015	#DIV/0!

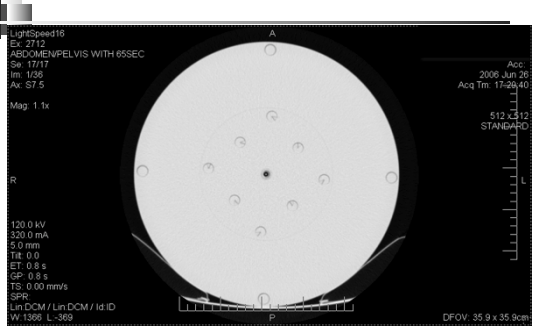
Head Dosimetry



CTDI Head Phantom (16-cm diameter PMMA Phantom)	Measured	Calculated
KVp	120	
mA	200	
Exposure time per rotation (s)	2	
Z axis collimation T (mm)1	5	
# data channels used (N)1	2	
	10	
Active Chamber length (mm)	100	
Chamber correction factor	1	
Center		
Measurement 1 (mR)	941.3	
Measurement 2 (mR)	942.9	
Measurement 3 (mR)	944	
Average of above 3 measurements (mR)		942.7
Head CTDI at isocenter in phantom (mGy)		82.0
12 o'clock position		
Measurement 1 (mR)	961.6	
Measurement 2 (mR)	963.9	
Measurement 3 (mR)	966.1	
Average of above 3 measurements (mR)		963.9
Head CTDI at 12 o'clock position in phantom (mGy)		83.9
CTDIw (mGy)		83.2
Clinical exam dose estimates (using measured CTDIw and site's Adult Head Protocol from Table 1)		
CTDIvol (mGy)	=CTDIw*N*T/I	83.2
DLP (mGy-cm)	=CTDIvol*17.5	1456.8
Eff Dose (mSv)	=DLP*0.0023	3.4

Displayed CTDIvol = 84.0 mGy

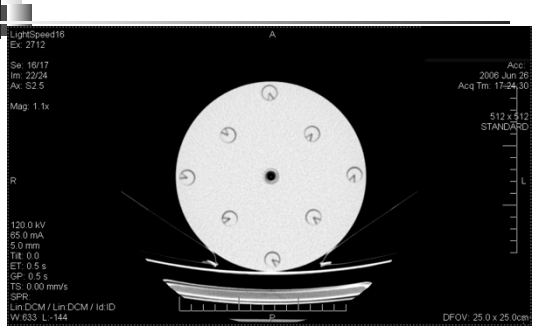
Adult Abdomen Dosimetry



CTDI Body Phantom (32-cm diameter PMMA Phantom)	Measured	Calculated
KVp	120	
mA	320	
Exposure time per rotation (s)	0.8	
Z axis collimation T (mm)1	5	
# data channels used (N)1	4	
	27.5	
Active Chamber length (mm)	100	
Chamber correction factor	1	
Center		
Measurement 1 (mR)	313.4	
Measurement 2 (mR)	314.8	
Measurement 3 (mR)	315.4	
Average of above 3 measurements (mR)		314.5
Body CTDI at isocenter in phantom (mGy)		13.7
12 o'clock position		
Measurement 1 (mR)	653.2	
Measurement 2 (mR)	620.5	
Measurement 3 (mR)	620.5	
Average of above 3 measurements (mR)		631.4
Body CTDI at12 o'clock position in phantom (mGy)		27.5
CTDIw (mGy)		22.9
Clinical exam dose estimates (using measured CTDIw and site's Adult Abdomen Protocol from Table 1)		
CTDIvol (mGy)	=CTDIw*N*T/I	16.6
DLP (mGy-cm)	=CTDIvol*25	415.9
Eff Dose (mSv)	=DLP*0.015	6.2

Displayed CTDIvol = 16.9 mGy

Pediatric Abdomen Dosimetry



Common Pitfalls

- Paperwork
- Phantom
- Dose

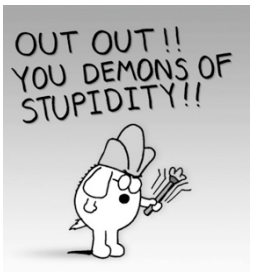


Table 1

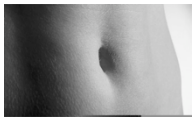
Table 1: Typical Image Acquisition Technical Parameters

	Adult Head (cerebellum portion)	High Resolution Chest	Adult Abdomen	Pediatric Abdomen (5 y.o.)
kVp				
mA				
Time per rotation (s)				
Scan FOV(cm or name)				
Display FOV (cm)				
Reconstruction Algorithm				
Axial (A) or Helical (H)				
Z-axis collimation (T, in mm)				
# data channels used (N)				
A: Table increment (mm) or H: Table Speed (mm/rot) (I)				
Pitch				
Reconstructed Scan Width (mm)				
Reconstructed Scan Interval (mm)				
Dose Reduction Techniques(s)				

- Ensure that you have this
- Ensure that the data matches what they do clinically
- Verify that default protocol matches
- Evaluate to ensure that all entries are appropriate

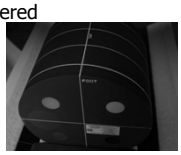
mA Modulation?

- More common on modern scanners
- Do not use for Table 1, Phantom or Dose
- Determine typical mA value for your site
  - Level of umbilicus good reference
  - "Typical" patient
  - Use this value for Table 1, Phantom and Dose



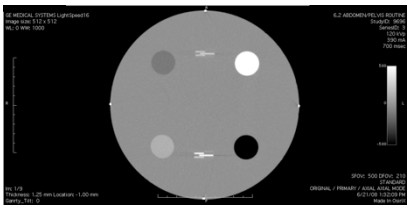
Alignment Accuracy

- "Use your site's high resolution chest technique to acquire a single axial scan at the landmark location"
- 0.625 mm?
  - Difficult to position
  - Must see 4 beads, 1 line centered
  - ONLY for < 1 mm
- Bad information in Table 1?
  - 3 mm



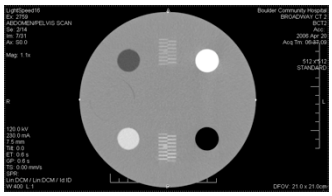
Alignment Accuracy

- ⇒ MUST use slice thickness less than 2 mm
  - ⇒ Except for the Siemens scanner that can't go less than 2.4 mm in axial mode!



CT Number Accuracy

- "using the technique factors listed for the Adult Abdomen technique"
  - 140 kVp?
  - Field of view?



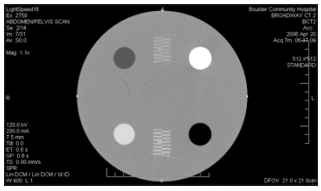
CT Number Accuracy

- Use **SCAN** FOV appropriate for the phantom size
  - Display FOV must still be 21 cm
- Use 120 kVp (or 130 kVp if 120 unavailable)
- Must provide water CT # for **ALL** kVp settings

Slice Thickness

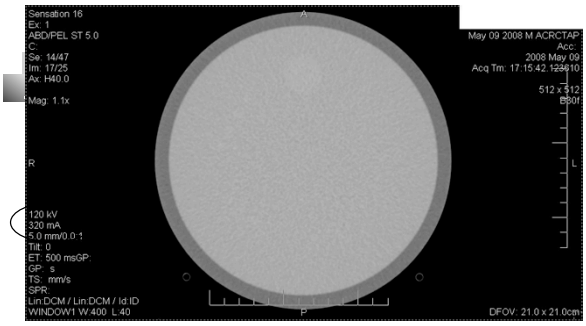
- New scanners may not allow larger slice thickness

⇒ Leave "~7 mm" box blank



Low Contrast

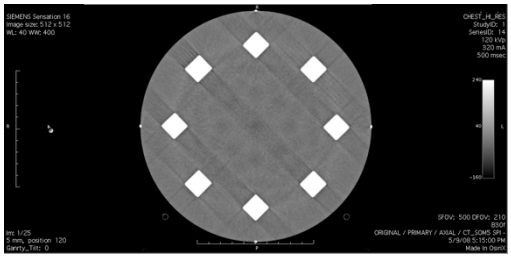
- Use ***clinical*** scan protocols
  - Must use correct mAs – match Table 1
  - If helical, must be helical
  - Must use correct pitch – match Table 1
- Must use WW=100, WL=100



- Most scanners give some indication of helical scanning (pitch, eff. mAs, etc.)
- May not appear if PACS used – best to comment

Spatial Resolution

- Must use clinical protocols
  - Slice thickness
  - Helical
  - Reconstruction algorithm
- Must use correct window width/level
- Must use 21 cm DFOV



Dosimetry

- Ignore paper forms if provided with package
- Must use Excel spreadsheets
- Must use ***correct*** Excel spreadsheets
- Ensure correct N, T, I entered
  - May not match Table 1 if axial-helical conversion not direct
- Verify that calculated values make sense!

CTDI Head Phantom (16-cm diameter PMMA Phantom)	Measured	Calculated
kVp	120	
mA	250	
Exposure time per rotation (s)	0.8	
Z axis collimation T (mm)[1]	5	
# data channels *used* (N)[1]	4	
Axial (A): Table Increment (mm) = (I)[1] OR Helical (H):Table Speed (mm/rot) = (I)[1]	1	
Active Chamber length (mm)	100	
Chamber correction factor	1	
Center		
Measurement 1 (mR)	950	
Measurement 2 (mR)	955	
Measurement 3 (mR)	955	
Average of above 3 measurements (mR)		953.3
Head CTDI at isocenter in phantom (mGy)		41.5
12 o'clock position		
Measurement 1 (mR)	954	
Measurement 2 (mR)	954	
Measurement 3 (mR)	952	
Average of above 3 measurements (mR)		953.3
Head CTDI at 12 o'clock position in phantom (mGy)		41.5
CTDIw (mGy)		41.5
Clinical exam dose estimates (using measured CTDIw and site's Adult Head Protocol from Table 1)		
CTDIvol (mGy)	=CTDIw*N*T/I	829.4
DLP (mGy-cm)	=CTDIvol*17.5	14514.5
Eff Dose (mSv)	=DLP*0.0023	33.4

Physics Input

- Doses
  - New ACR limits (head higher, abd lower)
  - Appropriate for scanner
  - Dose modulation
  - Pediatric
- Auto mA
  - Proper setting
    - Reference mA on Siemens
    - "Noise Index" on GE

Physics Input

- Reconstruction algorithms
  - High Res Chest
    - Very sharp algorithm
    - B71S (or higher) for Siemens
    - BONE for GE
- Slice thickness
  - Be aware of standard of practice
  - 10 mm head?
- High Res Chest from helical lung
- Image Gently
  - Pediatric doses scaled appropriately

Conclusions

- ACR is responding to concerns, albeit at a pace slower than some might like
- Most mistakes, and failures, can be avoided by carefully following the directions and thinking about each step
- Be actively involved in your site
  - No "phantom physicist"
  - Provide support, not just testing

For More Information

- Highly recommend:

  The phantom portion of the American College of Radiology (ACR) Computed Tomography (CT) accreditation program: Practical tips, artifact examples, and pitfalls to avoid

  Med. Phys. 31 (9), September 2004, pp. 2423 - 2442.

www.imagegently.org

The Maximum Permissible CTDIvol for Pediatric Abdomen is

1. 15 mGy
2. 20 mGy
3. 25 mGy
4. 30 mGy
5. 35 mGy

10

The Maximum Permissible CTDIvol for Pediatric Abdomen is

- 15 mGy
- 20 mGy – Ped. Abd. ref. dose
- **25 mGy**
- 30 mGy – Adult Abd. ref. dose
- 35 mGy – Adult Abd. max dose

McCullough, C, et al. "Radiation Doses from the ACR CT Accreditation Program: Review of Data Since Program Inception and Proposals for New Reference Values and Pass/ Fail Limits", presented at RSNA 2006

When scanning the phantom on a unit with automatic mA adjustment,

1. the mA specified in the ACR instructions should be used
2. the automatic mA feature should be used
3. the mA for the protocol should be used
4. the mA for average patients should be used
5. maximum mA for the protocol should be used

10

When scanning the phantom on a unit with automatic mA adjustment,

1. the mA specified in the ACR instructions should be used
- the automatic mA feature should be used
- the mA for the protocol should be used
- **the mA for average patients should be used**
- maximum mA for the protocol should be used

Updated Site Scanning instructions, American College of Radiology CT Accreditation Program. Dina Hernandez, Program Specialist CT/MR Accreditation, American College of Radiology, private communication.