



*Dose Alerts, Dose Notifications, and
Diagnostic Reference Levels:
How are they different?*

Dianna Cody, PhD, FAAPM

Professor and Section Head, Radiologic Physics
MD Anderson, Houston, TX

Cynthia H. McCollough, PhD, FAAPM, FACR

Professor of Radiologic Physics
Mayo Clinic, Rochester, MN



DC DISCLOSURES

Paid Speaker: MTMI, Inc.

Off Label Usage

None



CHM DISCLOSURES

Research Support:

NIH	Other
EB 007986	Society of Gastrointestinal Radiologists
EB 004898	Mayo Novel Methodology Development Award
DK 083007	Thrasher Foundation
DK 059933	Siemens Healthcare
DK 090728	
AR 057902	
RR 018898	

Off Label Usage

None



DC and CHM DISCLOSURES

Other

ACR CT Accreditation Program

Past Chairs and/or Members of Physics Subcommittee



What is the “right” dose?

- The one that makes pretty pictures
- The one that the vendor specifies
- The one that you used previously
- The one presented at meetings
- The one that keeps the radiologists happy (i.e., they don't complain)
- The lowest one you can still read
- The one “proven” to provide the required diagnostic accuracy



Diagnostic Reference Levels

- First mentioned by the International Commission on Radiological Protection (ICRP) in 1990
 - (ICRP 60)
- Recommended in greater detail in 1996
 - (ICRP 73)



Diagnostic Reference Levels

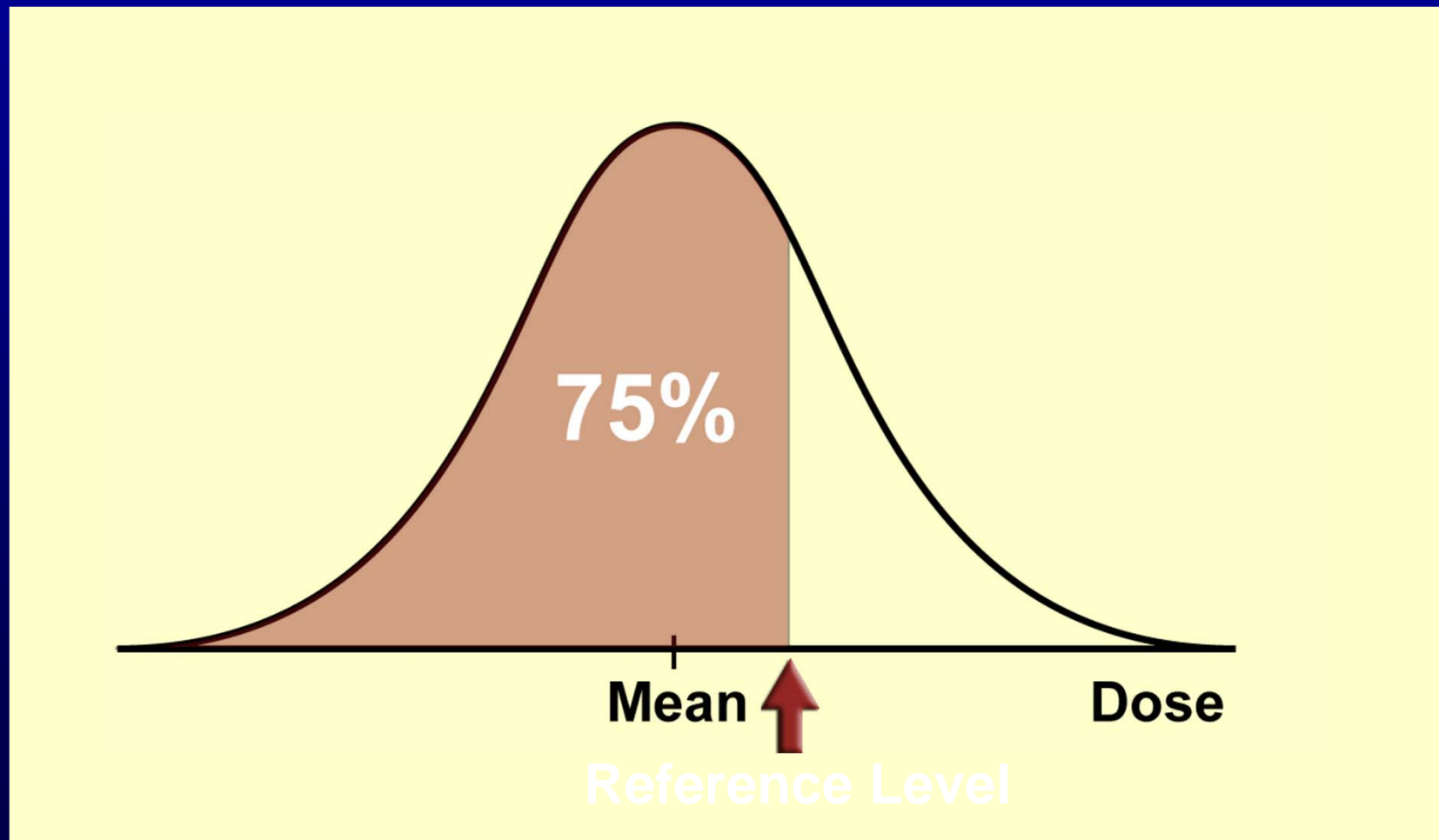
- DRLs are a form of investigation level used as a simple test to identify situations where patient dose is unusually high
- Employ an easily measured and standardized quantity (not effective dose)
- If consistently exceeded, a local review of procedures and equipment should be performed
- If possible, dose reduction measures should be taken



Diagnostic Reference Levels

- Diagnostic reference levels are supplements to professional judgment and do not provide a dividing line between good and bad medicine.
- It is inappropriate to use them for regulatory or commercial purposes.
- Apply to medical exposures, not to occupational and public exposures.
- The values should be selected by professional medical bodies and reviewed at appropriate intervals.

In practice, it is simpler to choose an initial Reference Level Value as a percentile point on the observed distribution of doses in patient exams.





Reference Level Concept Endorsed by

- European Commission
- U.K. Health Protection Agency
- International Atomic Energy Agency
- National Council on Radiation Protection
- American Association of Physicists in Medicine
- American College of Radiology



U.K. Experience

- Perform regular national dose surveys
 - National Radiation Protection Board (NRPB)
- Demonstrated decreases in typical radiographic doses
 - 30% between 1984 and 1995
 - 50% between 1985 and 2000
- Reflect equipment improvements and the trend over time to reduce dose
- Data points above 75th %tile to be investigated
- Resulting adjustments narrow the dose distribution and lower the mean dose



-
- DRLs must
 - be defined in terms of an easily and reproducibly measured dose metric
 - use technique parameters that reflect those used in site's routine clinical practice for average patient size
 - Some surveys determine typical technique parameters and model dose metric of interest
 - Increases uncertainty due to equipment variations
 - Radiographic: Entrance Skin Exposure
 - Fluoroscopic: Dose Area Product
 - CT: CTDI_w, CTDI_{vol}, and DLP



DRLs from Other Countries

Adult Diagnostic Reference Levels for CTDI_w (mGy) and DLP (mGy·cm)

	Head		Abdomen		Pelvis		Abd & Pelvis	
	CTDI _w	DLP	CTDI _w	DLP	CTDI _w	DLP	CTDI _w	DLP
EC 1999	60	1050	35	900	-	-	35	780
ACR 2002	60	-	35	-	-	-	-	-
UK 2003	-	930	20	470	-	-	20	560
Germany 2003	60	1050	25	770	-	-	24	1500
Switzerland 2004	60	800	20	710	30	540	-	-
Taiwan 2007	72	850	31	680	28	520	-	-

EC: European Commission

ACR: American College of Radiology

UK: United Kingdom



DRLs from Other Countries

Adult Diagnostic Reference Levels for CTDI_{vol} (mGy) and DLP (mGy·cm)

	Head		Abdomen		Pelvis		Abd & Pelvis	
	CTDI _{vol}	DLP	CTDI _{vol}	DLP	CTDI _{vol}	DLP	CTDI _{vol}	DLP
Sweden 2002	75	1200	25	-	-	-	-	-
UK 2003	65-100	930	14	470	-	-	14	560
Netherlands 2008	-	-	-	-	-	-	15	700
EC 2004	60	-	25	-	-	-	15	700
ACR 2008	75	-	25	-	-	-	-	-

EC: European Commission

ACR: American College of Radiology

UK: United Kingdom



U.S. ACR CT Accreditation Data

- Program initiated in 2002
- CTDI_w measurements made for
 - Routine adult head (16 cm)
 - Pediatric abdomen (typical 5 year old, 16 cm)
 - Routine adult abdomen (32 cm)
- CTDI_{vol} calculated using typical scan parameters
- Manual review of CTDI images and reported data performed to ensure integrity of database (i.e. exclude suspicious data points)

- ACR CTDI_w Reference Doses

- Adult Head 60 mGy*
- Adult Abdomen 35 mGy*
- Pediatric (5 yr old) Abdomen 25 mGy

- Originally no pass/fail dose criteria

**European Commission EUR 16262 (2000)
European Guidelines on Quality Criteria for Computed Tomography*



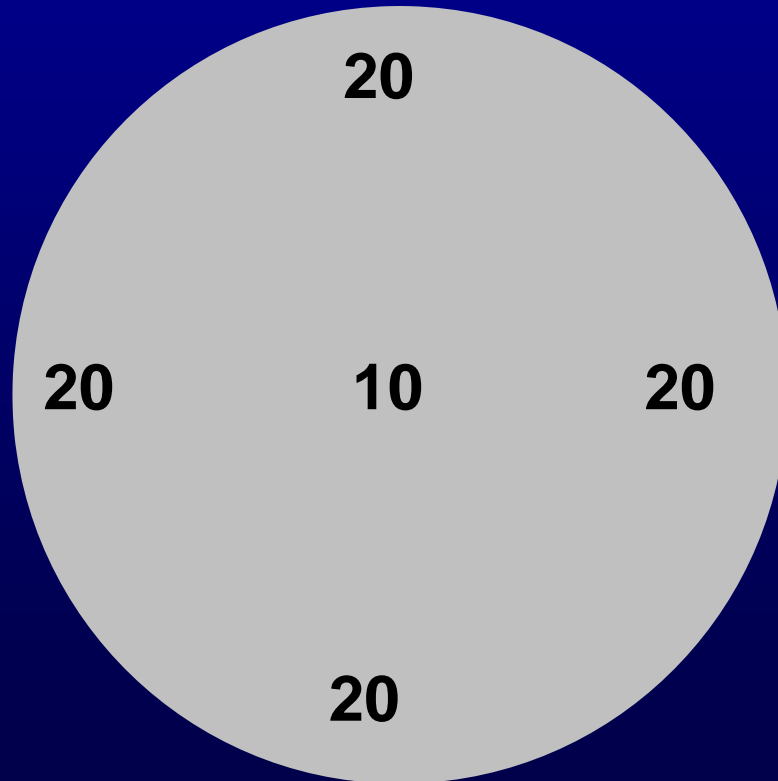
Phantom size affects CTDI values

Same kVp, beam width, pitch

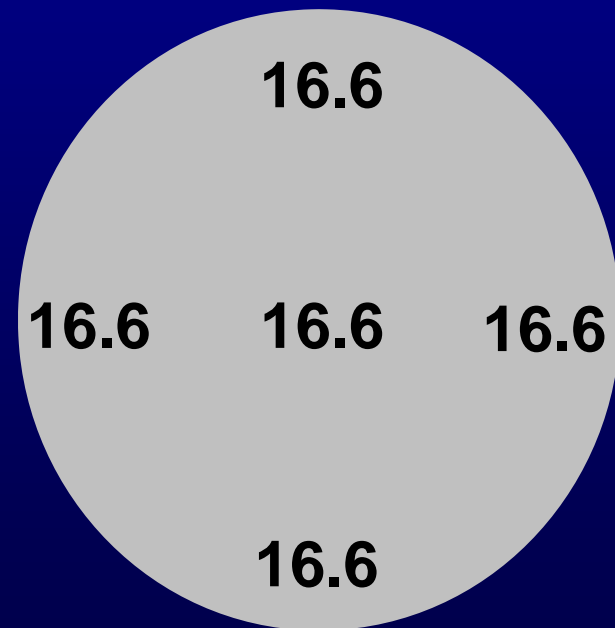
Body (32 cm)
280 mAs

$\div 2.4 =$

Head (16 cm)
116 mAs



CTDI_w = 16.6



CTDI_w = 16.6

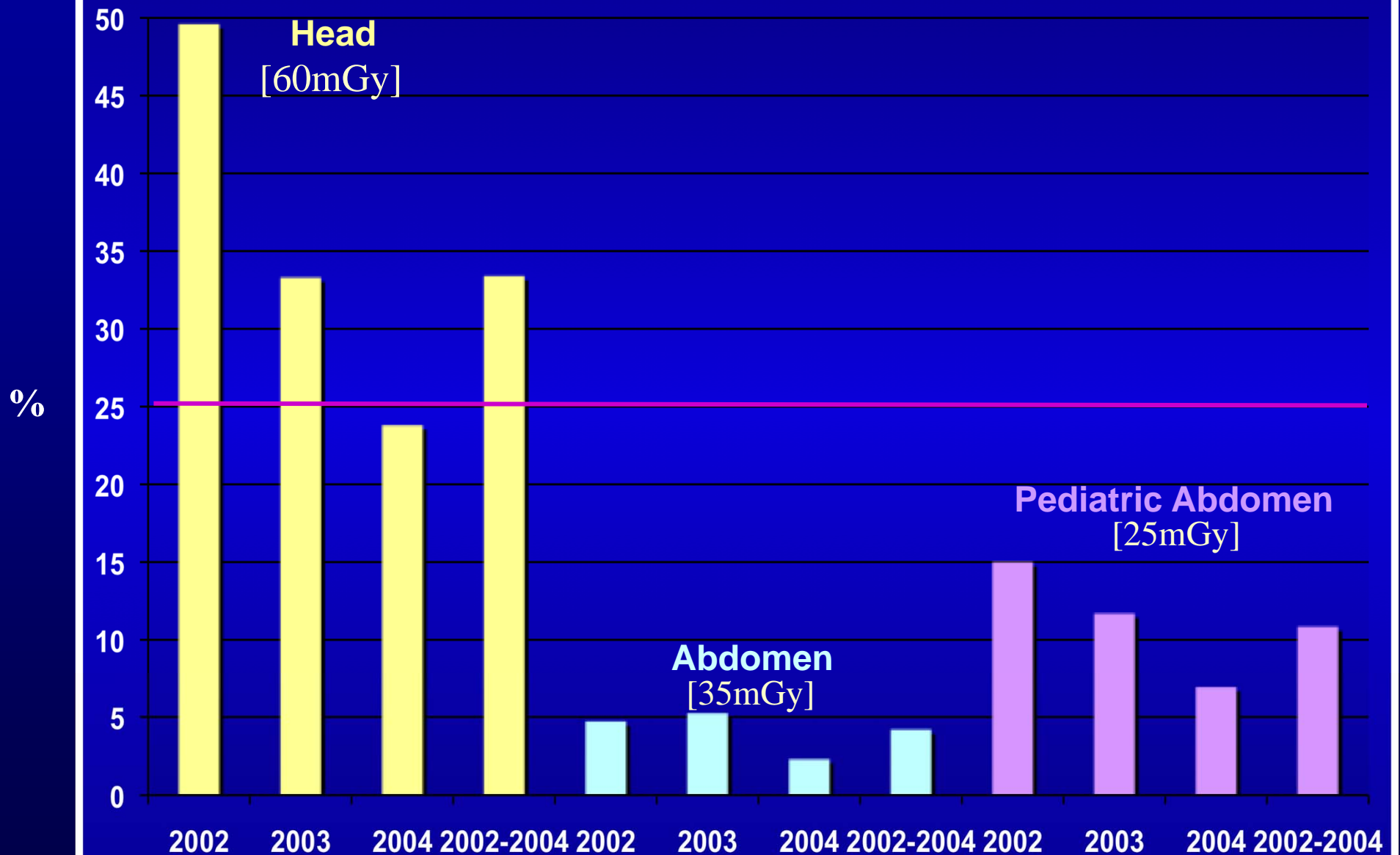


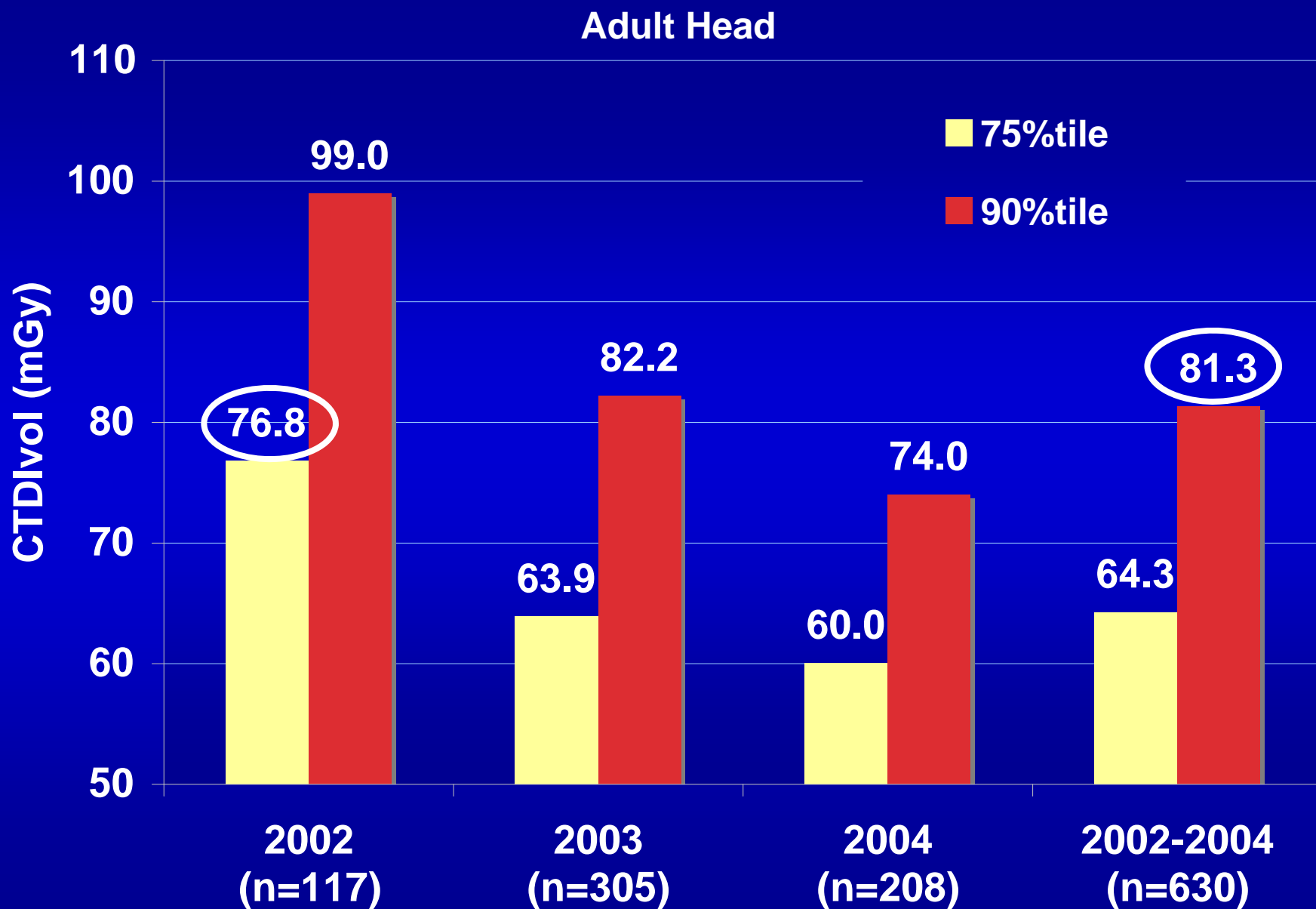
Phantom size affects CTDI values

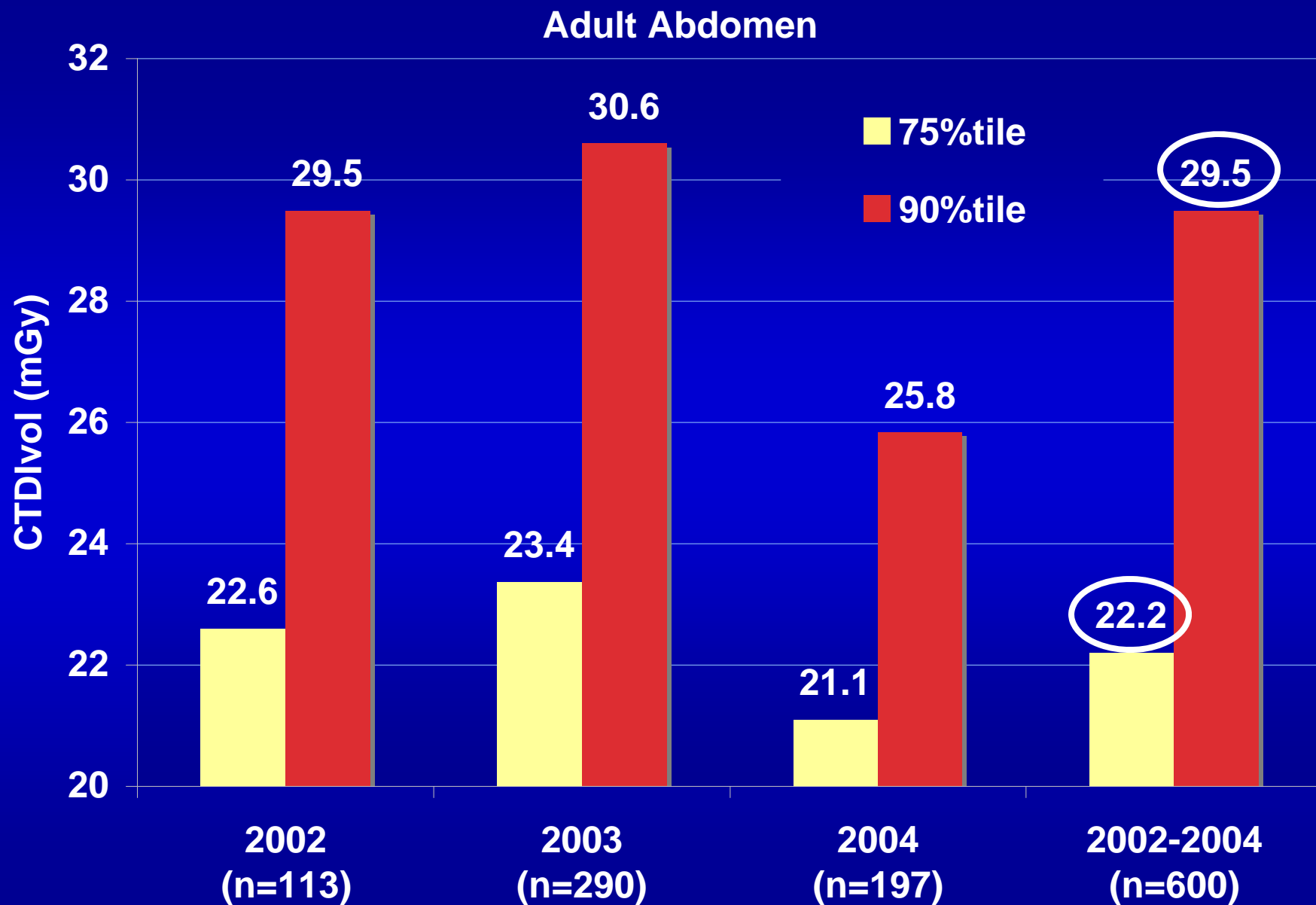
- Use of smaller phantom and lower reference value implies that a reduction in tube output by a factor of to 3 - 4 is expected for a 5 y.o. abdomen exam
- Body CTDI_{vol} values displayed on the scanner console are supposed to use large CTDI phantom*
 - Siemens and Philips – large (32 cm)
 - GE, Toshiba and Hitachi – small (16 cm)
 - Standards, professional and manufacturer organizations are working toward harmonization on this important issue

% > 2002 Reference (CTDIw)

In Press, AJR

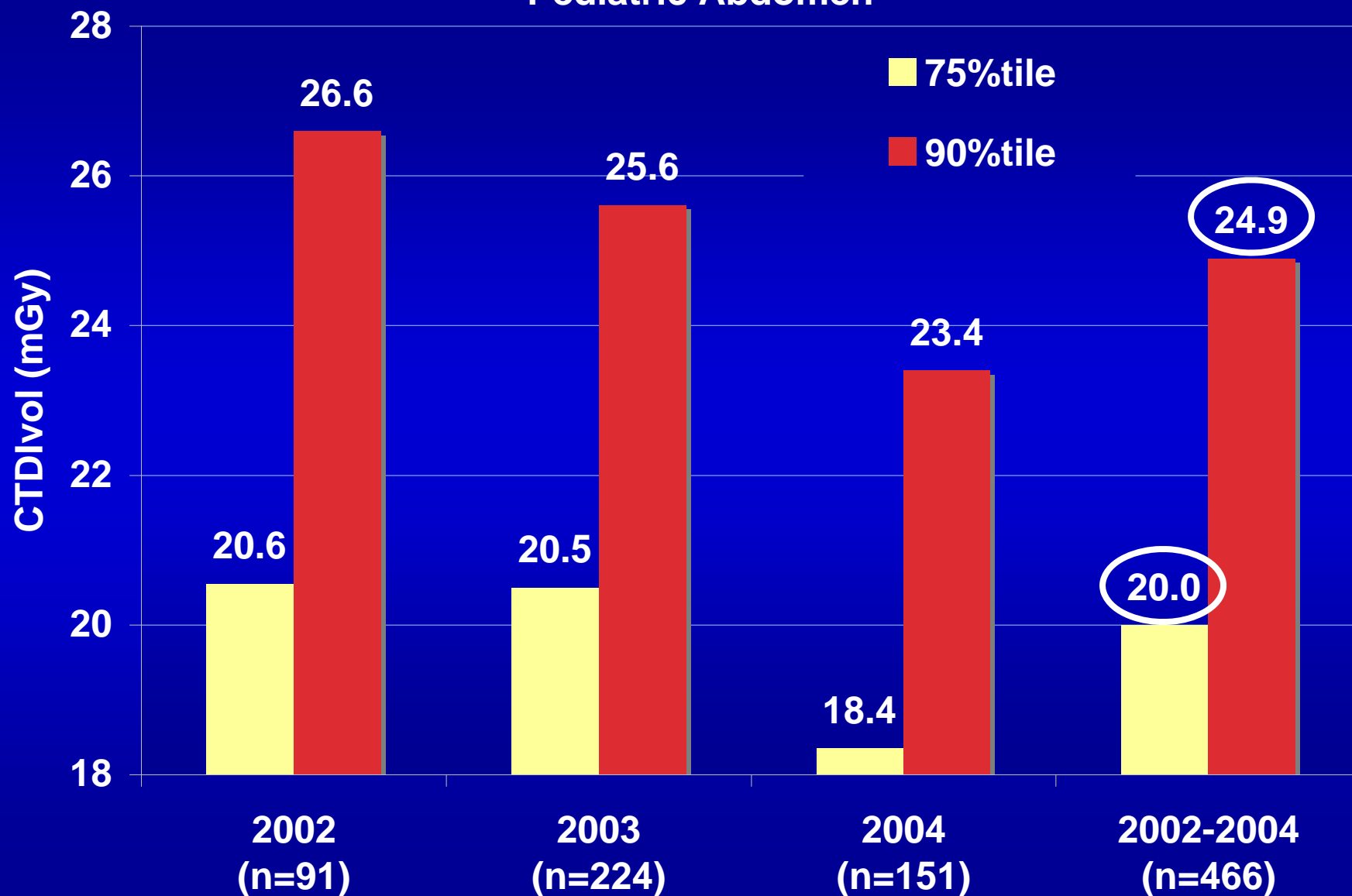








Pediatric Abdomen





ACR CT Accreditation Program

- Established U.S. CT diagnostic reference levels
- Based on CTDIvol to include the effect of pitch
- Reference doses (site given educational information)
 - Adult Head 60 → 75 mGy
 - Adult Abdomen 35 → 25 mGy
 - Pediatric (5 yr old) Abdomen 25 → 20 mGy
- Maximum allowable doses (site fails if exceeded)
 - Adult Head 80 mGy
 - Adult Abdomen 30 mGy
 - Pediatric (5 yr old) Abdomen 25 mGy



DRLs for Other Exams

- Many more CT exam types exist
- To extend benefits of DRL concept, dose surveys required for broader range of exams
- Data sources
 - European community
 - ACR CTDI registry – CTDIvol / DLP from DICOM header
 - Multi-center studies (e.g. Protection I coronary CTA)
 - Individual sites/investigators



DRLs for Other Exams

- The results of these surveys may extend the value of DRLs to the majority of CT applications, enabling individual CT users and the community at large to answer the question:

“What CT doses are typical and what doses are too high?”



DRLs vs Dose Notifications and Alerts

- Need tools at the point of care that inform users if there is a potential prescription error [FDA]
 - For a specific diagnostic task (e.g. routine head)
 - “ ... inform users when scan settings would likely yield values of CTDIvol that would exceed pre-assigned values”
- NEMA XR 25 CT Dose-Check Standard
 - <http://www.nema.org/stds/xr25.cfm>
- Notification value – for a single scan series
- Alert value – cumulative over entire exam
 - at a given table position




! DOSE ALERT
A dose alert value will be exceeded !
Proceeding with this exam will exceed the dose alert level that has been set.

	Predicted Dose	Alert Level
Cumulative CTDIvol	1263.7 mGy	1000.0 mGy
Patient total DLP	6643.0 mGy.cm	6500.0 mGy.cm

Dose Alert

A dose value will be exceeded!

 The accumulated CTDIvol (767.47 mGy) will locally exceed the alert value (700 mGy for Adult). Please reconsider the current examination procedure.

Hint: The currently used scan protocol can not be saved!

User name (mandatory)

Diagnostic reason

Dose Alert

Dose Alert - Alert value will be exceeded!

The scan has a CTDI_{vol} of 1255.6 mGy. This exceeds the Alert Value of 1000 mGy. This may result in an excessive level of radiation exposure

Enter user name: *

Enter diagnostic reason:

Enter password: *

Dose Alert

Seq. No.	CTDIvol[mGy]	DLP[mGy.cm]	Notification Value(DLP)[mGy.cm]
7	88.5	1327.1	150.0


Sum DLP[mGy.cm] : 1769.4
Alert Value(DLP)[mGy.cm] : 1000.0

A Dose Alert Value will be exceeded.

Please input a password and click the "Confirm" button to scan.

Password

DoseAlert

 The prescribed scan parameters result in a projected exam dose exceeding the user configured Alert Value. Select Cancel to go back to Viewedit and adjust scan parameters if clinically appropriate to set below the Alert Value. An authorized user name and password must be entered to select Confirm. Selecting Confirm will proceed to scan and log user confirmation of scan parameters exceeding the Alert Value.

	AV	Projected/Accumulated	Start	End
CTDIvol (mGy)	1000	2281.00	12.5	537.5

Logon Name:

Password:

Diagnostic Reason



AAPM Recommendations

- AAPM Working Group on Standardization of CT Nomenclature and Protocols, which includes members from the FDA, ACR, and manufacturers, established a particular set of notification values
- http://www.aapm.org/pubs/CTProtocols/documents/NotificationLevelsStatement_2011-04-27.pdf



Adult exams

CT Scan Region
(of each individual scan in an examination)

CTDIvol
Notification Value
(mGy)

Adult Head	80
Adult Torso	50



Why are notification values so much higher than DRLs?

- DRL values typically represent the 75th percentile from a regional or national sample of clinically used dose indices for a standard patient size
- Because ~1/3 of US population is obese, use of DRLs as notification values would result in notifications occurring very frequently, potentially de-sensitizing users and diminishing the potential value of notification values in avoiding erroneously high exposures



AAPM notification values > DRLs

- May allow higher-than-optimal dose settings in some cases, but because they will be triggered less frequently, the tendency for users to ignore the notifications might be reduced
- Children require different notification and alert values due to their smaller size





Pediatric exams

CT Scan Region (of each individual scan in an examination)	CTDI _{vol} Notification Value (mGy)
Pediatric Head	
<2 years old	50
2 – 5 years old	60
Pediatric Torso	
<10 years old (16-cm phantom) ^a	25
<10 years old (32-cm phantom) ^b	10

^a As of January 2011, GE, Hitachi and Toshiba scanners use the 16-cm-diameter CTDI phantom as the basis for evaluating dose indices (CTDI_{vol} and DLP) displayed and reported for pediatric body examinations.

^b As of January 2011, Siemens and Philips scanners use the 32-cm-diameter CTDI phantom as the basis for evaluating dose indices (CTDI_{vol} and DLP) displayed and reported for pediatric body examinations.



Specialty exams

CT Scan Region (of each individual scan in an examination)	CTDIvol Notification Value (mGy)
Brain Perfusion (examination that repeatedly scans the same anatomic level to measure the flow of contrast media through the anatomy)	600
Cardiac Retrospectively gated (spiral) Prospectively gated (sequential)	150 50



AAPM notification values are starting points

- As facilities gain more experience using the NEMA “CT Dose-Check” feature, they are encouraged to work with a medical physicist to adjust the values to better suit their individual practice
- The AAPM-recommended values do not correspond to optimal or “target” settings, are not considered acceptable “upper limits” of dose, and do not represent diagnostic reference levels



Thank you