Clinical Implementation of "Imaging Gently": What , Why & How

FLAAPM-FCHPS Fall 2008 Meeting

David E. Hintenlang, Ph.D., DABR, FACMP
University of Florida

Administrative note about this SAM/CE activity:

SAM participants: get a SAM handout, complete it, and return it to the FLAAPM Secretary for processing. *You will not receive SAM credit unless FLAAPM gets a completed SAM participation form from you.*

Participants will receive performance evaluation:

- An overall score
- Documentation of own vs. correct responses
- Feedback/references for incorrect responses
- Comparison of personal score to score distribution of the group

The Alliance for Radiation Safety in Pediatric Imaging

The campaign goal is to change practice by increasing awareness of the opportunities to lower radiation dose in the imaging of children.

The Image Gently Campaign

- **Founding Organizations:**
  - The Society for Pediatric Radiology
  - American Association of Physicists in Medicine
  - American College of Radiology
  - American Society of Radiologic Technologists

- Created: The Alliance for Radiation Safety in Pediatric Imaging

Alliance Organizatons

- Academy of Radiology Research
- American Academy of Pediatrics
- American College of Medical Physics
- American Institute of Ultrasound in Medicine (new 8/29/2008)
- American Osteopathic College of Radiology
- American Registry of Radiologic Technologists
- American Roentgen Ray Society
- American Society of Emergency Radiology
- American Society of Pediatric Neuroradiology
- Asian-Oceanic Society for Paediatric Radiology (new 7/23/2008)
- Association of University Radiologists
- Canadian Association of Radiologists
- Coalition for Imaging and Bioengineering Research (new 8/7/2008)
- Conference of Radiation Control Program Directors
- European Society of Paediatric Radiology (new 9/2/2008)
- National Council on Radiation Protection and Measurements
- North American Society for Cardiovascular Imaging (new 8/1/2008)
- Radiological Society of North America.
- The Royal Australian and New Zealand College of Radiologists (new 8/12/2008)
- Society of Interventional Radiology (new 8/13/2008)
- Sociedad Latino Americana de Radiología Pediátrica
- Society for Pediatric Interventional Radiology
- Society of Computed Body Tomography and Magnetic Resonance
- Society of Gastrointestinal Radiologists
- The Society of Nuclear Medicine
- The Society of Nuclear Medicine - Technologist Section
- Society of Radiologists in Ultrasound
- Society of Uroradiology

A team approach:

- Community radiologists
- Technologists
- Medical Physicists
- Parents

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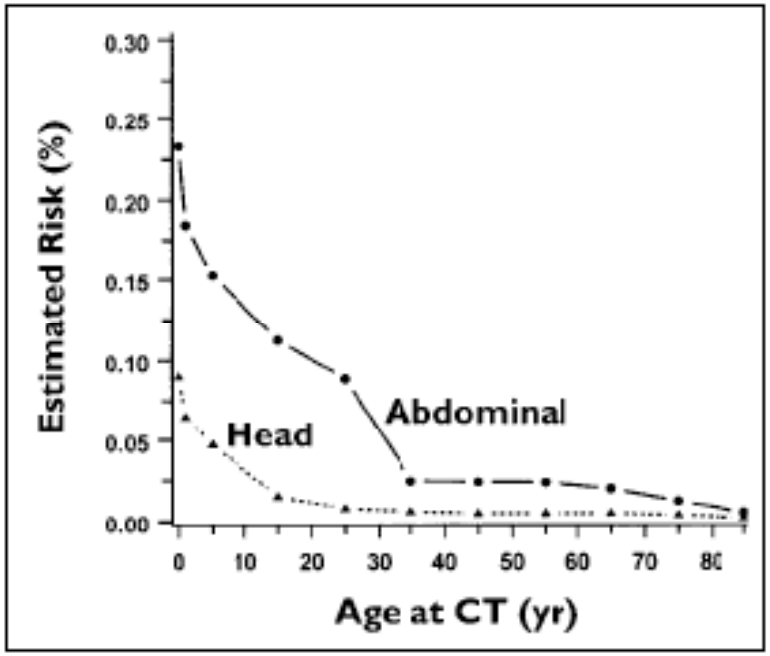
Why the focus on Pediatric CT?

- Public concerns of potential CT risks
- Brenner et.al. American Journal of Roentgenography, 2001.



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Brenner and Hall, NEJM 2007

- 62 Million CT scans
- At least 4 million on children

In summary, there is direct evidence from epidemiologic studies that the organ doses corresponding to a common CT study (two or three scans, resulting in a dose in the range of 30 to 90 mSv) result in an increased risk of cancer. The evidence is reasonably convincing for adults and very convincing for children.

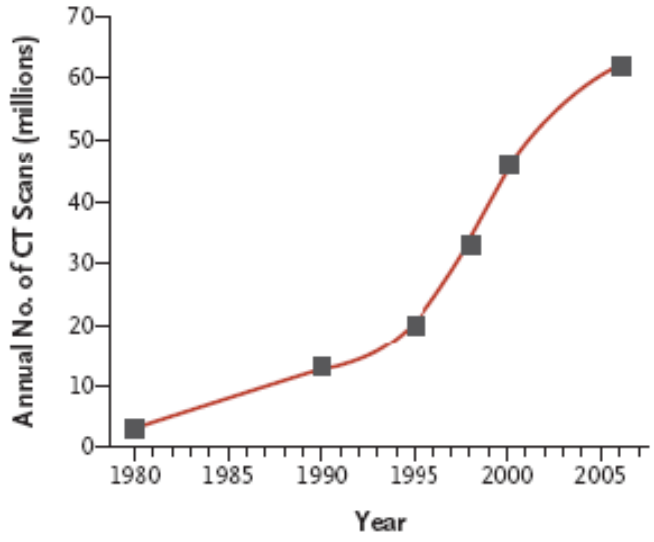

Figure 2. Estimated Number of CT Scans Performed Annually in the United States.

The most recent estimate of 62 million CT scans in 2006 is from an IMV CT Market Summary Report.[3]

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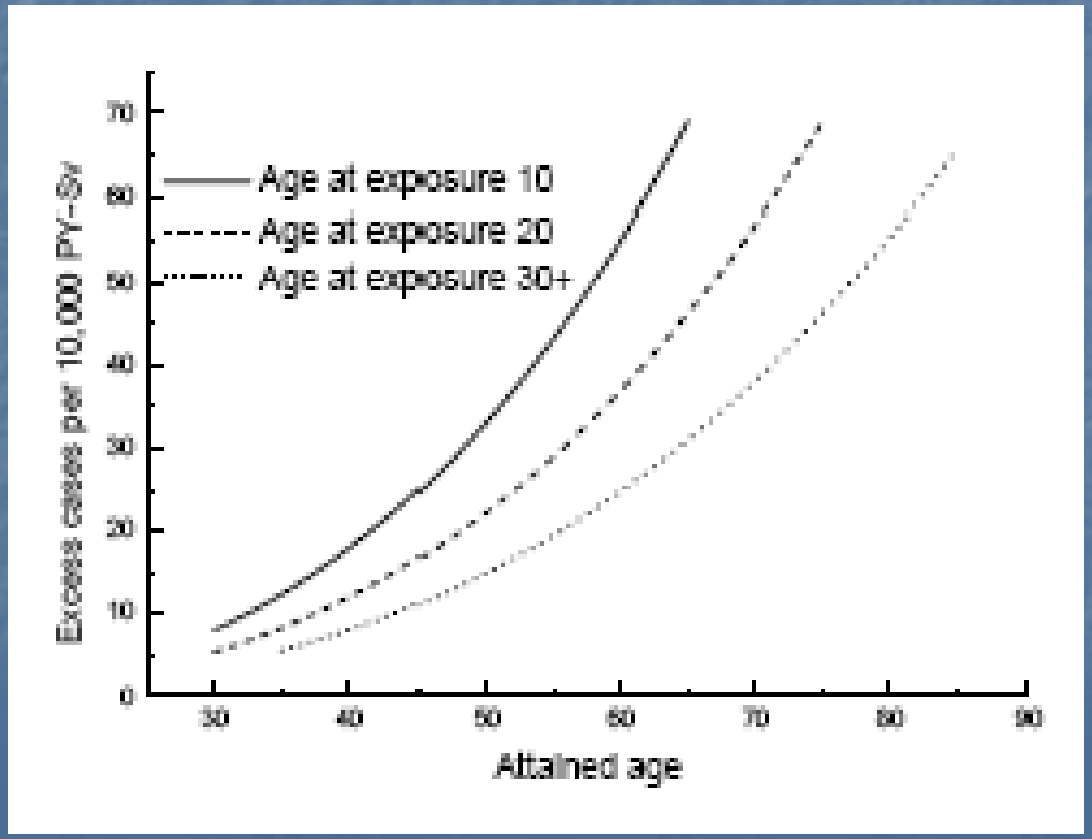
Excess Cancer Cases (Radiation Induced Risk) vs Attained Age

- BEIR VII



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1: The goal of the Image Gently Campaign is

A. to raise awareness of the opportunities to lower radiation dose in the imaging of children.

B. provide a forum for professional societies to interact directly with CT manufacturers.

C. support the development of more strict regulatory standards for pediatric doses.

D. provide CT protocols that will meet the ACR CT accreditation pass/fail requirements for CT dose.

E. to raise funds to support further research into medical radiation effects to children.

Answer: A. to raise awareness of the opportunities to lower radiation dose in the imaging of children.

Ref: www.imagegently.org

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2: The excess cancer cases from CT examinations are generally expected to

A. decrease with decreasing age of exposure and increase with increasing attained age.

B. decrease with increasing age of exposure and increase with increasing attained age.

C. increase with increasing age of exposure and decrease with increasing attained age.

D. increase with both increasing age of exposure and increasing attained age.

E. decrease with both increasing age of exposure and increasing attained age.

Answer: B. decrease with increasing age of exposure and increase with increasing attained age.

Ref: Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII – Phase 2, Washington D.C., The National Academies Press, 2005.,www.nap.edu

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Physicists' contributions:

- Dose evaluation and quanitification
- Evaluation of image quality
- Protocol development and verification

Quantifying the CT "Dose"

- Effective dose
  - Weighted sum of organ doses
  - Intended to reflect overall (whole body) risk
  - Does not reflect organ specific risks for partial body scans
  - Accurate measurement of organ doses

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Quantifying the CT "Dose"

- CT Dose Index: CTDI
- $CTDI_w$ – Intended to provide an average dose across the transverse plane of the patient.
- $CTDI_{vol}$ – Extrapolates $CTDI_w$ to a volumetric average by including pitch in the calculation.
  - ACR Pass/Fail Standards now based on $CTDI_{vol}$

	Adult Abdomen	Pediatric Abdomen
Pass/Fail $CTDI_{vol}$	30 mGy	25 mGy
Reference $CTDI_{vol}$	25 mGy	20 mGy

Pediatric Imaging

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Dose Calculator Spreadsheet (Exposure)

CTAP ID Number

Section 10 - Radiation Dosimetry (Ped Body)

Use the TAB key to move between data entry cells in the column named *Measured*.

CTDI Head Phantom (16-cm diameter PMMA Phantom)	Measured	Calculated
kVp	120	
mA	60	
Exposure time per rotation (s)	0.8	
Z axis collimation T (mm)[1]	2.5	
# data channels *used* (N)[1]	4	
Axial (A): Table Increment (mm) = (I)[1] OR	7.5	
Active Chamber length (mm)	100	
Chamber correction factor	1	
Center		
Measurement 1 (mR)	99.15	
Measurement 2 (mR)	99.25	
Measurement 3 (mR)	99.25	
Average of above 3 measurements (mR)		99.2
Ped Body CTDI at isocenter in phantom (mGy)		8.6
12 o'clock position		
Measurement 1 (mR)	100.8	
Measurement 2 (mR)	100.75	

CTDIw (mGy)		8.7
Clinical exam dose estimates (using measured CTDIw and site's Pediatric Abdomen Protocol from Table 1)		
CTDIvol (mGy)	=CTDIw*N*T/I	11.6
DLP (mGy-cm)	=CTDIvol*15	174.4
Eff Dose (mSv)	=DLP*0.0081*2.6	3.7

Estimated effective dose based on

- Measured $CTDI_w$
- Scaled to $CTDI_{vol}$
- Assumed scan length
  - 15 cm Ped
  - 25 cm Adult
- Scaling factors from “old” MCNP studies

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Evaluation of Image Quality

- Subjectively quantified by low contrast tools; ACR or other Image Quality Phantoms
- Decreased dose results in increased quantum noise.
- Limits determined by tolerance of radiologist
- Image Gently – encourages increased tolerance

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Proposed Image Gently Protocol

- "How to Develop CT Protocols for Children"
- Concept: Reduce mAs based on adult protocols
- "Reduction Factors" function of
  - Patient age, or
  - Patient thickness

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Procedure

A. Establish baseline techniques for an adult head and abdomen CT.

1. Your medical physicist should determine the $CTDI_{vol}$ for an adult body phantom and an adult head phantom using the FDA 32 and 16 cm CTDI PMMA phantoms (29) respectively.

2. If the measured $CTDI_{vol}$ of the adult abdomen or head phantoms exceed the ACR CT Accreditation Program recommended upper values of 25 and 75 mGy respectively (20), work with your medical physicist to reduce either the tube

3. Record the final tube voltage (kVp), tube current (mA), rotation time (sec), pitch and bow tie filter settings in Tables I and II as your baseline techniques for the adult abdomen and head.

B. Determine the appropriate mAs for a pediatric thorax, abdomen and head CT.

1. Multiply the baseline (abdomen or head) mAs by the indicated Reduction Factor to determine the appropriate pediatric mAs and write this in the table for all patient PA thicknesses/ages or use attached Excel spread sheet to automatically perform these calculations.)

2. The other techniques in your protocol (kVp, pitch, and bow tie filter) must remain the same. ***You should verify with your CT manufacturer that the bow tie filter in the scanner does not change if the FOV is reduced for pediatric patients.***

3. If the pitch of your thorax and abdomen scans is different, ask your medical physicist to calculate the correct Thorax Baseline from your Abdomen Baseline. Alternatively, the attached Excel spread sheet automatically performs this correction if you enter the different pitch values in the spreadsheet.

4. When examining pediatric patients, find the mAs Reduction Factor from the completed tables that corresponds to the applicable PA thickness/age.

5. **The mAs ratios in Tables I and II assume that the kVp used for a pediatric examination is the same as the kVp used to determine the baseline mAs for either the head or the abdomen.** If you elect to use a reduced kVp for pediatric examinations, the suggested mAs ratios in these tables do not apply.

Simplified Instructions

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- Start with an appropriate Adult Protocol
- Determine age, or AP thickness of Ped patient
- Look up the Reduction Factor (Abdomen, Thorax or Head)
- Multiply the Adult mAs by the RF to get the Pediatric mAs (kVp remains constant).

Abdomen Baseline:	kVp=	mA=	Time= sec	Pitch Abdomen=	Pitch Thorax=
PA Thickness (cm)	Approx Age	Abdomen		Thorax	
		mAs Reduction Factor (RF)	Estimated mAs = BL x RF *(fill in)*	mAs Reduction Factor (RF)	Estimated mAs = BL x RF *(fill in)*
9	newborn	0.43		0.42	
12	1 yr	0.51		0.49	
14	5 yr	0.59		0.57	
16	10 yr	0.66		0.64	
19	15 yr	0.76		0.73	
22	small adult	0.90		0.82	
25	med adult	Baseline (BL)		0.91	
31	large adult	1.27		1.16	

3: The Alliance for Radiation Safety in Pediatric Imaging recommends a technique to develop CT protocols for children based on

A. a set of tabulated values of kVp, mAs, and pitch for various sizes of pediatric patients.

B. incorporating mA modulation into routine scanning protocols.

C. scaling the kVp from adult protocols to specific patient sizes.

D. scaling the mAs from adult protocols to specific patient sizes.

E. incorporating appropriate bow-tie filters and increasing the pitch for pediatric scans.

Answer: D. scaling the mAs from adult protocols to specific patient sizes.

Ref: "How to Develop CT Protocols for Children", http://www.pedrad.org/associations/5364/files/Protocols.pdf

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4: The ACR Accreditation Dose Requirements for the Pediatric Abdomen (5 yr old) is 25 mGy of the measured quantity

A. $CTDI_{100}$

B. CTDIw.

C. CTDIvol.

D. DLP

E. Effective Dose.

Answer: C. CTDIvol.

Ref: American College of Radiology, "CT Accreditation Program Requirements", http://www.acr.org/accreditation/computed/ct_reqs.aspx

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Example:

- Adult Technique: 120 kVp, 150 mAs
- Pediatric Patient: 5 yr old

Abdomen Baseline:	kVp=	mA=	Time= sec	Pitch Abdomen=	Pitch Thorax=
PA Thickness (cm)	Approx Age	Abdomen		Thorax	
		mAs Reduction Factor (RF)	Estimated mAs = BL x RF *(fill in)*	mAs Reduction Factor (RF)	Estimated mAs = BL x RF *(fill in)*
9	newborn	0.43		0.42	
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22	small adult	0.90		0.82	
25	med adult	Baseline (BL)		0.91	
31	large adult	1.27		1.16	

How well does it work?

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- Measurements performed for a GE 16 Slice scanner

- Adult Abdomen Technique (120 kVp, 150 mAs)
  - 18.0 mGy = $CTDI_{vol}$
- Using the Adult Technique on Ped Abdomen
  - 36.3 mGy = $CTDI_{vol}$
  - Note: Does not satisfy the ACR Ped Body Dose Requirement
- Proposed Ped Technique (120 kVp, 88.5 mAs)
  - 21.3 mGy = $CTDI_{vol}$
  - Not quite as low as adult
- Actual Ped Technique (120 kVp, 48 mAs)
  - 11.6 mGy = $CTDI_{vol}$

5: Based on the following table, a facility that uses an Adult Head protocol of 120 kVp, 250 mAs, pitch=1, the "Image Gently" CT protocol for a 1 yr old patient would be

A. 120 kVp, 125 mAs, pitch=1

B. 120 kVp, 200 mAs, pitch = 1

C. 100 kVp, 250 mAs, pitch = 2

D. 100 kVp, 125 mAs, pitch = 0.5

E. 80 kVp, 250 mAs, pitch = 1.

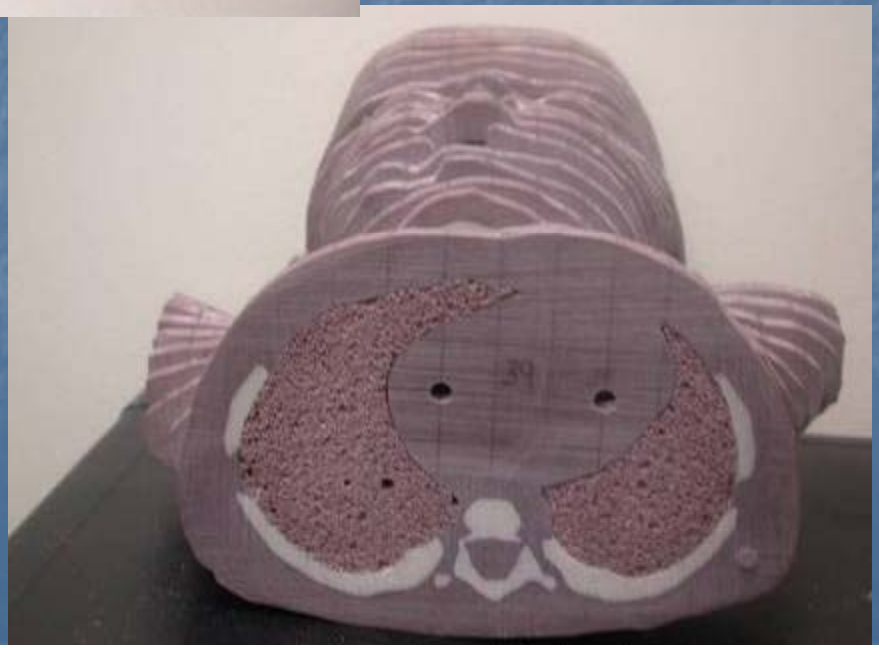
	kVp	mAs Reduction Factor (RF)
Abdomen Baseline:	120	250
		Abdomen
PA Thickness (cm)	**Approx Age**	**mAs Reduction Factor (RF)**
9	newborn	0.43
12	1 yr	0.51
14	5 yr	0.59
16	10 yr	0.66
19	15 yr	0.76
22	small adult	0.90
25	med adult	1.0
31	large adult	1.27

Answer: A. 120 kVp, 125 mAs, pitch=1.

Ref: "How to Develop CT Protocols for Children", http://www.pedrad.org/associations/5364/files/Protocols.pdf

Example 2:

- Previous example illustrates a reduction in the $CTDI_{vol}$ but not demonstrated for organ doses, or effective dose.
- Performed a series of phantom measurements using an anthropomorphic model of a 1 yr old.



Adult Technique- 150 mAs

	32 cm Cylinder	16 cm Cylinder	1 Yr Old
$CTDI_w$ (mGy)	12.4	27.1	
Organ Dose (mGy)			25.5
Effective Dose (mSv)	1.8	4	9.3

Peds Adusted Technique- 76 mAs

	32 cm Cylinder	16 cm Cylinder	1 Yr Old
$CTDI_w$ (mGy)		15.4	
Organ Dose (mGy)			16.1
Effective Dose (mSv)		2.3	5.8

Other Dose Reduction Considerations

- kVp
- Pitch Changes
- mA Modulation
- Bow-Tie Filters
- Breast Shields
- Console Indication of CTDI

Changing kVp

- Additional dose reductions can be achieved by appropriate reductions in kVp.
- Frush provides tables based on patient weight for typical techniques.
- For 5 yr old example:
- 100-120 kVp, 60 mA, 0.5 s, pitch= 0.75
- Results in 11.6 mGy
- Lower kVp recommended for extremities

Pitch Changes

- Pitch may change between adult and pediatric techniques, or for abdomen and thorax protocols.
- Account for this by using *Effective mAs*

- *Effective mAs = mAs/Pitch = mAs NT/I*

mA Modulation

- Provides automatic correction of beam intensity to keep constant intensity at detector.
- Automatically reduction of mAs.
- User input maintains a minimum signal/noise for image quality.

Adult Technique- 150 mAs

	32 cm Cylinder	16 cm Cylinder	1 Yr Old	1 Yr Old w/ CareDose
$CTDI_w$ (mGy)	12.4	27.1		
Organ Dose (mGy)			25.5	11.9
Effective Dose (mSv)	1.8	4	9.3	4.3

Peds Adusted Technique- 76 mAs

	32 cm Cylinder	16 cm Cylinder	1 Yr Old	1 Yr Old w/ CareDose
$CTDI_w$ (mGy)		15.4		
Organ Dose (mGy)			16.1	7.1
Effective Dose (mSv)		2.3	5.8	2.6

- Bow-Tie Filters
  - Dose reduction protocol assumes that same bow-tie filters are present for corresponding adult/pediatric exam types.

- Breast Shields
  - Effectively reduces entrance exposure and dose to near surface organs
  - Little effect on image quality
  - Little effect on centrally located organs due to scatter contributions
  - More effective for large patients than small
  - Demonstrated to provide 25-35% dose reduction on peds.
  - Shouldn’t be used in conjunction with mA modulation

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Console indication of CTDI

- Some dose indication required for new scanners
- Present either $CTDI_w$ or $CTDI_{vol}$
- Compared console indication with measured CTDI for 15 scanners
  - 4 major manufacturers
  - Multiple models
- Console vs. Measured
  - Typically within 5% for adult body and head protocols
  - Console is about ***50% of measured for Pediatric body protocols***

Conclusions

- Image Gently Campaign focusing on reduction of pediatric doses in CT
  - May ultimately extend to other examinations and procedures
- Promotes a team approach:
  - Community radiologists
  - Pediatricians
  - Technologists
  - Physicists
  - Parents

Conclusions

- Provides a simple framework to ensure pediatric doses are no greater than adult doses
  - Reduction Factors for mAs scaling based on patient size
- More aggressive dose reductions can be achieved by incorporated kV changes, mA modulation, local shields, etc.
- Provides a number of resources on-line
- Take the Pledge at www.imagegently.org

References:

- Brenner DJ, Elliston CD, Hall EJ, and Berdon WE, Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT, AJR, 176, 289-296, 2001.
- Brenner DJ, Hall EJ, N Engl J Med, 357, 2277-2284, 2007.
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