Don't Electrocute Me!: Common Misconceptions in Imaging and Radiation Safety (and What to Do About Them)

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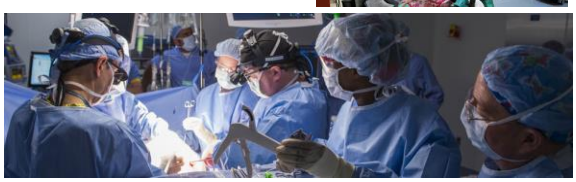
Who in the Facility Works With/Around Radiation?

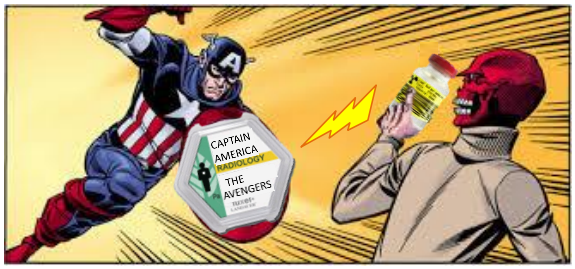
- Radiologists
- Radiation Oncologists
- Technologists
- Non-radiology physicians
  - Anesthesiologists
  - OB/Gyn
  - Cardiologists
  - Pain Management
  - Surgeons
  - ER physicians
- Nursing staff in *multiple* departments



Staff should understand what the risks *are* and what the risks *are not*

- Make well-informed choices concerning their own well-being
- Make well-informed choices about patients' medical care
- Communicate risks (or lack thereof) to patients
  - Allows patients to make well-informed decisions about their own health care
  - Allows patients to make well-informed decisions about their own health care

 # 1 "My personnel dosimeter will stop the radiation."



 # 1a "These latex gloves will protect me from the radiation"

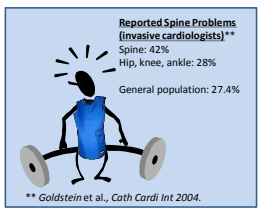
Take-home message:

Understand what protects you from radiation and what doesn't.

 # 2 "If one lead apron is good, then two must be better."

Lead Aprons & Thyroid Shields

- 0.5mm Pb-equivalent material attenuates about 98% of scattered X-rays*



** *Goldstein* et al., *Cath Cardi Int 2004.*

* *Pasciak*, et al. *Med Phys 2015*

2 "If one lead apron is good, then two must be better."

Lead Aprons & Thyroid Shields

- 0.5mm Pb-equivalent material attenuates about 98% of scattered X-rays*

Is the added dose savings biologically significant?

Annual Dose Limit
50 mSv

Pregnant Radiation Workers:
0.5 mSv/month to the fetus

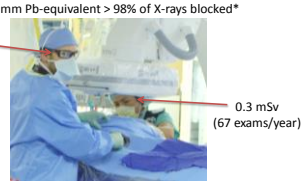
UCH Notification Levels:
ALARA 1: 10%
ALARA 2: 20%

2a Give me lead underwear!!

- Recent data (IAEA 2011) suggest a lens dose threshold of **500 mSv** (thought to be cumulative)
- NCRP recommends a maximum eye dose of **20 mSv/year** with no single year exceeding **50 mSv**

Dose to the lens per exam: 0.3 mSv (.01 mSv – 0.55 mSv) *(NCRP 168)*

0.75mm Pb-equivalent > 98% of X-rays blocked*



2a Give me lead underwear!!

2a Give me lead underwear!!

One study showed that using a leaded hat **reduced dose to the temple by 72%***

Threshold for effects to the brain from *acute* doses of radiation: **300 mSv**

ESE	* tissue weighting factor for the brain	* skull transmission	
ESE	* 0.01	* 0.66	= 0.66% of the ESE

	ESE per case (uGy)	Effective Dose, considering brain sensitivity & skull attenuation (uSv)	# of cases it would take to reach 300 mSv	Cases per year (45 year career)
without hat	200	1.3	> 200,000	> 5,000
with hat	56	0.37	> 800,000	> 17,000

Reeves, Society of Cardiovascular Angiography and Interventions (2014)

2b "Placing a lead apron on the patient will reduce operator dose."

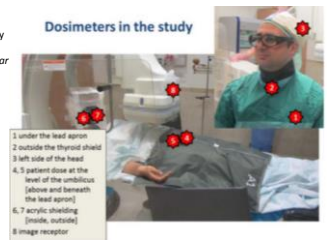
Recent studies:

* Placing a lead shield on the patient, and using a non-lead cap, reduced operator dose by 75%
(2014 College of Cardiology conference)

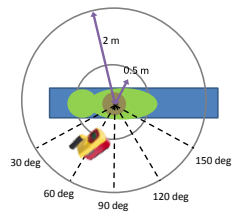
* Placing a lead shield on the patient decreased operator dose (under the operator's lead apron) by almost 70% for trans-radial interventions
(Masallan et al., *Catheterization and Cardiovascular Interventions, December 2014)*

Decreased the dose per procedure from 0.53 µSv to 0.17µSv

(AK of about 1100 mGy for each procedure)

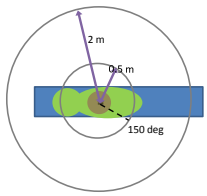


2b "Placing a lead apron on the patient will reduce operator dose."



With no Pb apron on the phantom
With an apron wrapped around the phantom
With an apron on the phantom *and* an apron in front of the scatter detector
With no apron on the phantom and an apron in front of the scatter detector

2b "Placing a lead apron on the patient will reduce operator dose."



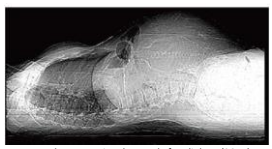
Take-home message:

Understand the limitations of protective equipment, and the risks associated with its over-use.

With no Pb apron on the phantom	100%
With an apron wrapped around the phantom	13%
With an apron on the phantom *and* an apron in front of the scatter detector	7%
With no apron on the phantom and an apron in front of the scatter detector	8%

NOT a statistically significant difference

3 "I would never let my pregnant wife get a head CT exam."



Lo, et al., *International Journal of Radiology (2014)*

Radiation Exposure to the Fetus	Increased Probability of Fetal Malformation or Miscarriage	Probability of Developing Childhood Cancer	
		1st Trimester	2nd or 3rd trimester
None	None	0.07%	0.07%
10 mGy	None	0.25%	0.12%
50 mGy	None	0.88%	0.3%

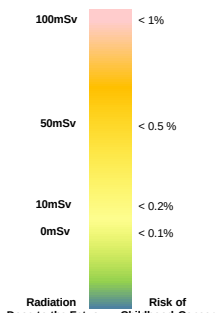
Wagner, Lester, & Saldana, "Exposure of the Pregnant Patient to Diagnostic Radiations," 1997.

Exam	Typical Fetal Dose
CT Scout	< 0.5 mSv
Extremity	< 0.01 mSv
Chest (including for PE)	0.2 mSv
Abdomen	4 mSv
Abdomen & Pelvis	25 mSv
Head:	Not Measurable

McCollough, et al., *Radiographics 2007; 27:909-18*

3 "I would never let my pregnant wife get a head CT exam."

Exam	Typical Dose to the Fetus
Mammography	
Mammogram (both breasts)	< 0.001 mSv
DEXA	
Dual X-ray Absorptiometry	< 0.001 mSv
X-ray	
Cervical spine, thoracic spine, extremity, or chest	< 0.003 mSv
Lumbar spine	1 mSv
Abdomen or pelvis	2 mSv
Fluoroscopy	
Small-bowel study	7 mSv
Double-contrast barium enema study	7 mSv
CT	
Head, Neck, Extremity, or Chest	< 1 mSv
Abdomen CT	4 mSv
Abdomen + Pelvis CT	25 mSv



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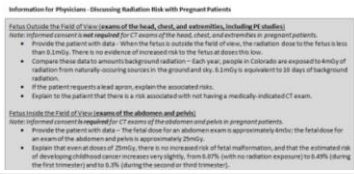


Information for Physicians - Discussing Radiation Risk with Pregnant Patients

Fetus Outside the Field of View (exams of the head, chest, and extremities, including PE studies)

Note: Informed consent is not required for CT exams of the head, chest, and extremities in pregnant patients.

- Provide the patient with data - When the fetus is outside the field of view, the radiation dose to the fetus is less than 0.1mGy. There is no evidence of increased risk to the fetus at doses this low.
- Compare these data to amounts background radiation -- Each year, people in Colorado are exposed to 4mGy of radiation from naturally-occuring sources in the ground and sky. 0.1mGy is equivalent to 10 days of background radiation.
- If the patient requests a lead apron, explain the associated risks.
- Explain to the patient that there is a risk associated with not having a medically-indicated CT exam.

Fetus Inside the Field of View (exams of the abdomen and pelvis)

Note: Informed consent is required for CT exams of the abdomen and pelvis in pregnant patients.

- Provide the patient with data -- The fetal dose for an abdomen exam is approximately 4mSv; the fetal dose for an exam of the abdomen and pelvis is approximately 25mGy.
- Explain that even at doses of 25mGy, there is no increased risk of fetal malformation, and that the estimated risk of developing childhood cancer increases very slightly, from 0.07% (with no radiation exposure) to 0.49% (during the first trimester) and to 0.3% (during the second or third trimester).

Take-home message:

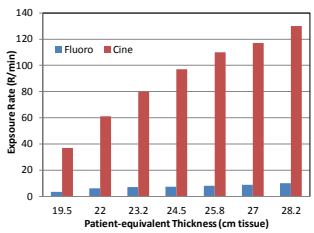
Understand which exams truly pose a risk to the patient and/or the fetus.

Suggested Key Phrases to Use When Discussing Radiation Risk with Pregnant Patients

- "We assess the appropriateness of every exam for every patient and have determined that this exam is will help provide you with the best care possible."
- "It is much more likely that you will benefit from the information provided by this exam than you or your child will experience any harm from the exam."
- "There is a risk associated with **not** having a medically-indicated CT exam."

4 "Fluoro and cine mode have the same dose rate."

Studies have found that the dose rate for cine acquisitions is **10 to 13 times higher** than for flouro modes*



** Cusma* et al., *JAC Cardiology 1999.*

4a "Room *X* always results in higher doses than Room *Y*"

Take-home message:

Air Kerma, and hence patient exposure, is affected by many factors.

	AK (mGy)	Fluoro Time (min)	# DSA Images	# Single Shot Images	Patient Size (BMI)??
Room Y_1	3180	35.4	165	2.3	
Room Y_2	2680	36.7	226	11.4	
Room X (New Room)	4657	52.3	376	19.8	
Patient Case	7000	100	505	56	

5 "Radiation was spilling out of the room." "I saw a fetus with radiation burns."

Who works in this area?

- Vascular surgeons
- OR nurses
- Anesthesiologists
- OB staff
- NICU staff

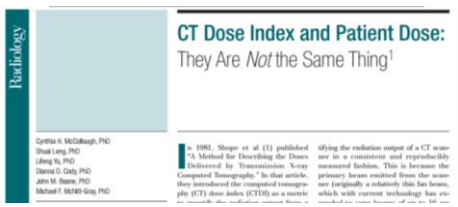
Take-home message:

A lack of information can cause rumors to get out of hand very quickly.

6 CTDI

"But do you mean the emitted $CTDI_{vol}$ or the absorbed $CTDI_{vol}$?"

"The $CTDI_{vol}$ for an adult abdomen exam should never be above 25 mGy."


Radiology

CT Dose Index and Patient Dose:
They Are *Not* the Same Thing[1]

Cynthia H. McCollough, PhD
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John M. Boone, PhD
Michael F. McNitt-Gray, PhD

In 1981, Shope et al (1) published "A Method for Describing the Doses Delivered by Transmission X-ray Computed Tomography." In that article, they introduced the computed tomography (CT) dose index (CTDI) as a metric ... quantifying the radiation output of a CT scanner in a consistent and reproducible measured fashion. This is because the primary beam emitted from the scanner (originally a relatively thin fan beam, which with current technology has ex-

6 $CTDI_{vol}$

"The $CTDI_{vol}$ for an adult abdomen exam should never be above 25 mGy."

ACR CT Accreditation Dose Pass/Fail Criteria and Reference Levels

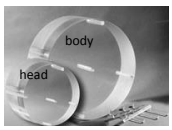
Examination	Pass/Fail Criteria $CTDI_{vol}$ (mGy)	Reference Levels $CTDI_{vol}$ (mGy)
Adult Head	80	75
Adult Abdomen	30	25
Pediatric Head (1 year old)	40	35
Pediatric Abdomen (40-50 lb.)	20	15

6 $CTDI_{vol}$

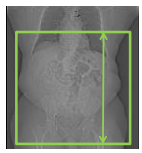
Total mAs 6442 Total DLP 2240 mGycm

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGycm	TI s	cSL mm
Patient Position F-SP							
Topogram	1	100	35 mA	0.09 L	5	6.3	0.6
Contrast							
CHEST/ABD	2	140	261 / 133	25.74 L	1136	0.5	0.6
ABD/PEL	3	140	233 / 133	22.95 L	1099	0.5	0.6

*: L = 32cm, S = 16cm



$CTDI_{vol}$
Dose to a Phantom



DLP
$CTDI_{vol}$ * Scan Length

$CTDI_{vol}$ = 22.95 mGy
scan length =

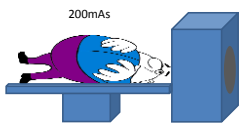
22.95 mGy * 47.89cm
= 1099 mGy*cm

6 $CTDI_{vol}$

CTDI ≠Patient Dose

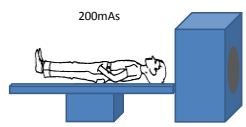
6 $CTDI_{vol}$

200mAs



$CTDI_{vol}$ = 20 mGy

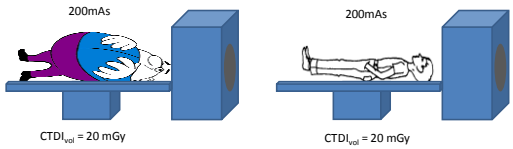
200mAs



$CTDI_{vol}$ = 20 mGy

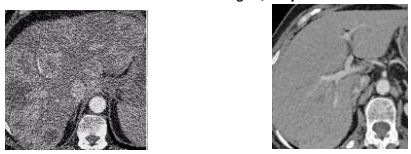
Which patient received a higher dose?

6 $CTDI_{vol}$

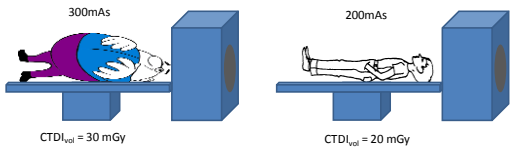


$CTDI_{vol}$ = 20 mGy $CTDI_{vol}$ = 20 mGy

What about Image Quality?



6 $CTDI_{vol}$



$CTDI_{vol}$ = 30 mGy $CTDI_{vol}$ = 20 mGy

Take-home message:
We expect $CTDI_{vol}$ to be higher for larger patients.

6a "We want to have the lowest CT dose in town"

What are the key goals in diagnostic radiology?

*To provide images that allow physicians to make accurate diagnoses, putting the patient at **as little risk as possible** to achieve this goal.*

Dose Optimization

6a "We want to have the lowest CT dose in town"

What are the key goals in diagnostic radiology?

*To provide images that allow physicians to make accurate diagnoses, putting the patient at **as little risk as possible** to achieve this goal.*

How low is too low?

6a "We want to have the lowest CT dose in town"

NRDR DIR® Dose Index Registry — American College of Radiology

Take-home message:

Understanding the role and limitations of dose indices is vitally important.

Exam	Site median $CTDI_{vol}$ (mGy)	Compared to Other Sites
CT CHEST WO IVCON	10	25th-50th Percentile
CT Pelvis WO IVCON	30	50th – 75th percentile
CT ABDOMEN	8	< 25th Percentile
CT HEAD	75	> 75th Percentile

Where do we want to be?

7 "I mag up to collimate."

Theory

Relative Exposure Rate: $(diameter_2/diameter_1)^2$

FOV (cm)	Dose Rate (mGy/min)
28	10
14	40

Philips Pulsera BV

OEC 9800 Plus

Effects of Magnification

FOV (cm)	Relative Dose Rate of Primary Beam (Meas./Theory)	Relative DAP Rate (Meas.)	FOV (cm)	Relative Dose Rate of Primary Beam (Meas./Theory)	Relative DAP Rate (Meas.)
12"	1 / 1	1	12"	1 / 1	1
9"	1.13 / 1.78	0.64	9"	1.64 / 1.78	0.92
7"	1.38 / 2.94	0.47	6"	2.78 / 4	0.70

 # 7 "I mag up to collimate."

Take-home message:

Collimating is preferable to magging up, when possible.

Effects of Collimation

FOV (cm)	Relative Dose Rate of Primary Beam (Meas.)	Relative DAP Rate (Meas.)
12"	1	1
6.2"	1	0.27

Effects of Magnification

FOV (cm)	Relative Dose Rate of Primary Beam (Meas./Theory)	Relative DAP Rate (Meas.)	FOV (cm)	Relative Dose Rate of Primary Beam (Meas./Theory)	Relative DAP Rate (Meas.)
12"	1 / 1	1	12"	1 / 1	1
9"	1.13 / 1.78	0.64	9"	1.64 / 1.78	0.92
7"	1.38 / 2.94	0.47	6"	2.78 / 4	0.70

 # 8 "Since you're not scanning a patient, can I take this tire iron into the MR scanner room?"

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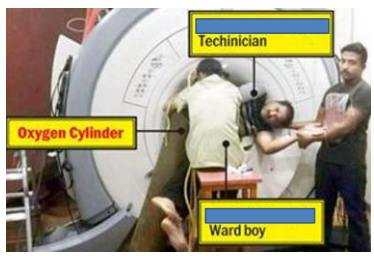
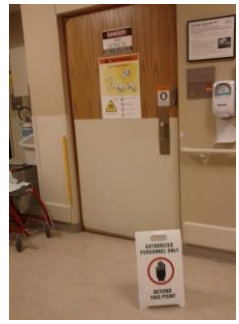


Mumbai, Nov 2014

 # 8 "Since you're not scanning a patient, can I take this tire iron into the MR scanner room?"



 # 8a "How much dose will my patient get from his MRI?"

Take-home message:
People don't pay attention to signs.

 # 9 "Your risk of developing cancer from this imaging exam is 2%"

Take-home message:
Resist the urge to take the easy road.

≠

"1 in 16 women will develop lung cancer in their lifetime"

"You have a 1 in 16 chance of developing lung cancer"

Models of radiation risk were never meant to be applied to an individual

Summary

- Tell them not to worry about it and that you know it's okay (this rarely works)
- Show them physics test results (this never works)

- Show them complete data (including number of acquisitions and/or patient size)
- Give them specific examples
- Compare these data with similar studies in the literature (when possible)
- "Trickle up" theory: Inform the technologists, nursing staff, and residents
- Try to predict when mis-understandings may occur (new rooms, equipment, etc.)
- Maintain a presence in the clinic
- Be patient

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