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Radiation Dosimetry and Cancer risks of Imaging

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Harvard Catalyst Imaging Consortium

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Harvard Catalyst Imaging Consortium

- **Provide expert consultation and guidance to the CTSC participants in the use of imaging as part of clinical translational research**
- **Educate and advise about available imaging and image processing capabilities in the Harvard environment**

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Harvard Catalyst Imaging Consortium

Massachusetts General Hospital	Bruce Rosen, Director Randy Gollub, Co-Director Gordon J. Harris, Consultant William Hanlon, Consultant
Beth Israel Deaconess Medical Center	Robert Lenkinski, Consultant Ivan Pedrosa, Consultant
BWH Brigham and Women's Hospital A Teaching Affiliate of Harvard Medical School	Clare Tempany, Consultant Ron Kikinis, Consultant Charles Guttmann, Consultant Todd Perlstein, Consultant Gordon Williams, PI for CTSC Translational Technologies
Children's Hospital Boston The Hospital for Children	Stephan Voss, Consultant Simon Warfield, Consultant
Dana-Farber Cancer Institute	Annick D. Van den Abbeele, Consultant Jeffrey Yap, Consultant, Director of Education
Harvard Catalyst The Harvard Clinical and Translational Science Center	Valerie Humblet, Imaging Liaison Yong Gao, Imaging Informatics Architect

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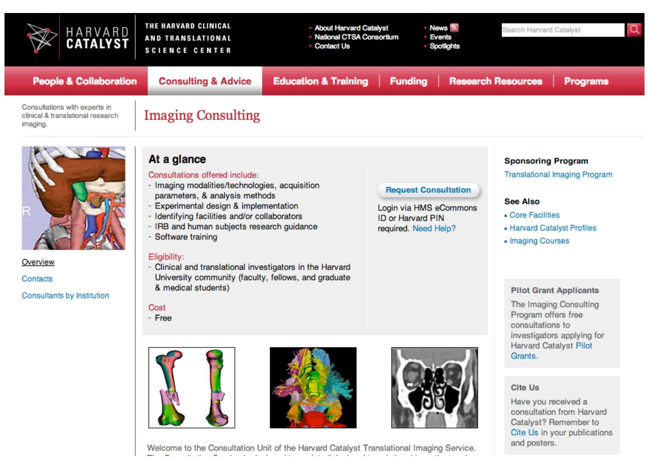
Harvard Catalyst Imaging Consortium

http://catalyst.harvard.edu/services/imagingconsult/



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Objectives

- **Learn the imaging modalities that involve ionizing radiation**
- **Understand the potential risks of ionizing radiation used in imaging**
- **Learn the ALARA principle and some of the techniques used to reduce radiation exposure**
- **Understand the radiation safety protocol screening form and model consent risk statements**

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Benefits versus Risks

- **We must focus on knowing/reducing the risks. Benefits should always outweigh the risks**

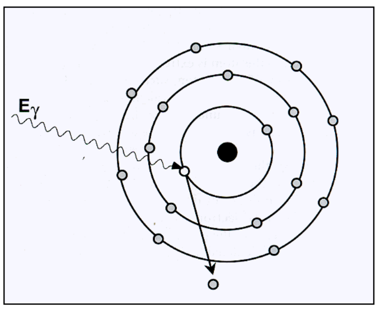
Risks
Claustrophobia
Discomfort
Noise
Radiation Exposure
Contrast reactions

Benefits
Non-invasive
Early detection
Staging
Response assessment
Pharmacokinetics
Pharmacodynamics
Biopsy/Surgical guidance
Safety monitoring

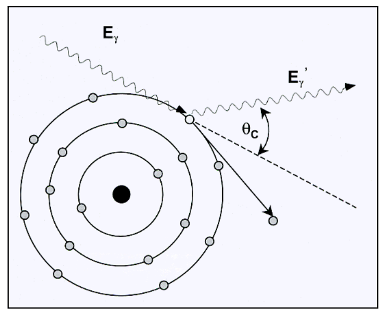
Definition of Ionizing Radiation

- **High energy radiation that detach electrons from atoms or molecules resulting in an ionized particle**

Photoelectric effect



Compton scattering



Sources of ionizing radiation

Higher Dose

- **Nuclear Reactors**
- **Radiation therapy (external beam, brachytherapy)**
- **Therapeutic nuclear medicine (e.g. ^{131}Iodine, Bexxar, Quadramet)**
- **Diagnostic Imaging**
- **Cosmic radiation**
- **Radon and other naturally occurring radioisotopes**

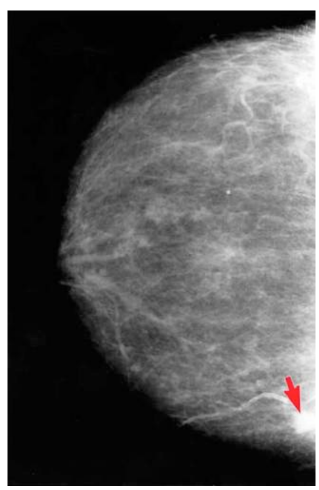
Lower Dose

Imaging modalities that use *ionizing* radiation

- Radiology
  - X-ray
  - Dual Energy X-ray Absorptiometry (DEXA)
  - Fluoroscopy
  - Mammography
  - Computed Tomography (CT, CAT scan)
- Nuclear medicine
  - Gamma camera (e.g. bone scans, MUGA)
  - Single photo emission computed tomography (SPECT)
  - Positron emission tomography (PET)

Mammography

- Very low radiation dose procedure
- High spatial resolution capable of detecting small lesions
- Used for early detection in routine screening and surveillance
- Only used for detecting locoregional disease (not a whole-body technique)



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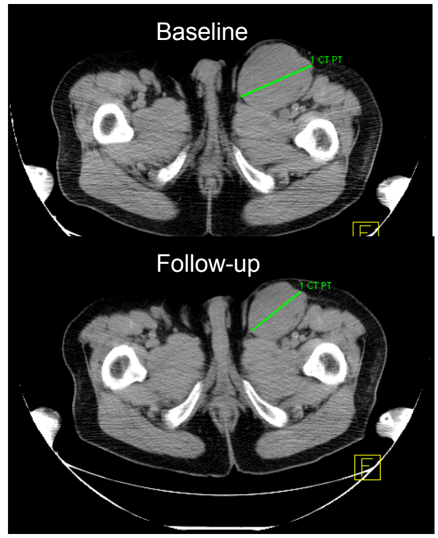
X-ray Computed Tomography (CT)

- **3-dimensional whole-body imaging**
- **Higher radiation dose than planar x-ray**
- **To provide information about the size and location of the tumor and whether it has spread;**
- **Ideal for image guidance (biopsy/surgery/radiation)**
- **Standard for response assessment in clinical oncology trials**



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Bone Scintigraphy (Bone scan)

- **Nuclear medicine technique using ^{99m}Tc-MDP to measure bone function**
- **Can detect arthritis, infection (cellulitis or osteomyelitis), tumors, fractures**
- **Used in protocol screening for bone metastasis (e.g. breast, prostate cancer)**

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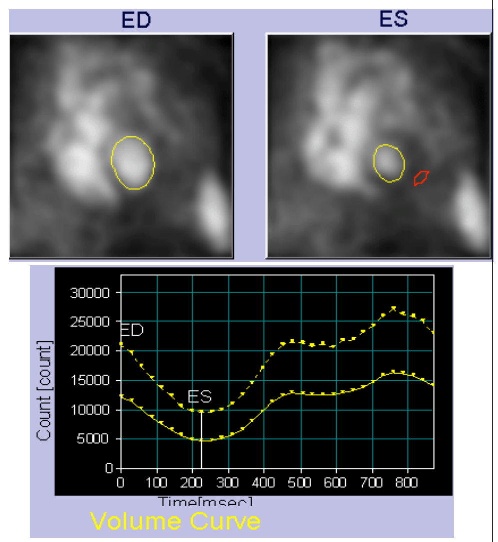
RVG/MUGA scan

- Can detect wall motion abnormalities
- Estimate cardiac ejection fraction
- Used in screening for trial eligibility
- Performed during or after treatment for safety monitoring (cardiotoxicity)
- Uses ^{99m}Tc-labelled red blood cells



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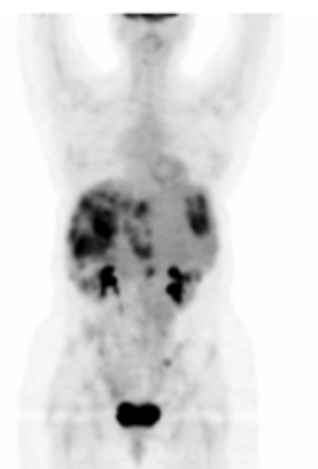
Positron Emission Tomography

- Functional and molecular imaging modality
- Can detect early disease and response to therapy



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Imaging Modalities that involve *non-ionizing* radiation

- **Photography**
- **Optical imaging**
- **Bioluminesence**
- **Ultrasound (e.g. sonogram, echocardiogram)**
- **Magnetic Resonance Imaging (MRI)**
  - Nuclear Magnetic Resonance (NMR)
  - Functional MRI (fMRI)
  - MR Spectroscopy (MRS)

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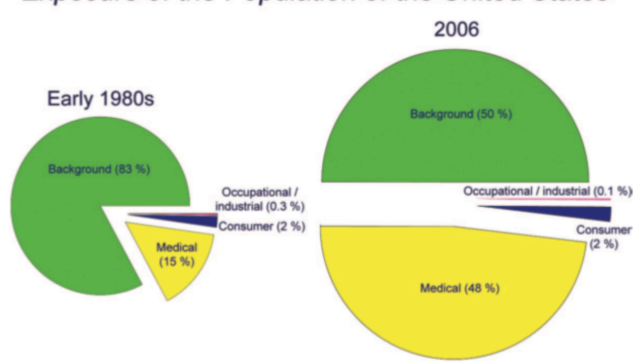
Increase in radiation exposure

NCRP Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*



	Early 1980s	2006
Collective effective dose (person-Sv)	835,000	1,870,000
Effective dose per individual in the U.S. population (mSv)	3.6	6.2

Radiation risks

- **Very high dose radiation can have immediate tissue damage and risk of future cancer (deterministic effect)**
  - Examples: radiation therapy, radiation burns from overdose, workers in nuclear disaster
- **Low dose radiation may have increased long term risk of cancer (stochastic effect)**
- **Most stochastic risk models are based on survivors of catastrophic radiation incidents (atom bomb, Chernobyl)**

Why increase in dose?

Dose is related to image quality

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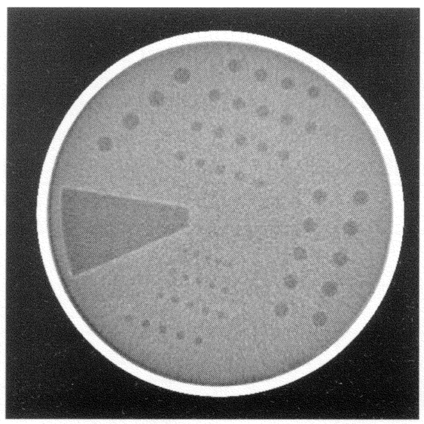
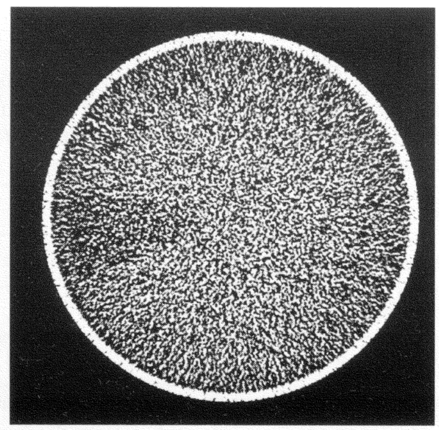
Why increase in dose?

High dose scan



Low dose scan



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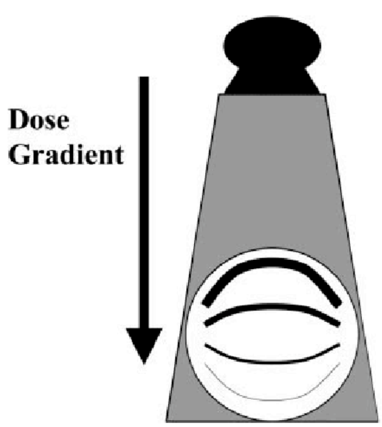
How do we estimate radiation dose from imaging procedures?

Conventional radiography



x-ray skin dose
2 mGy/0.2 rad

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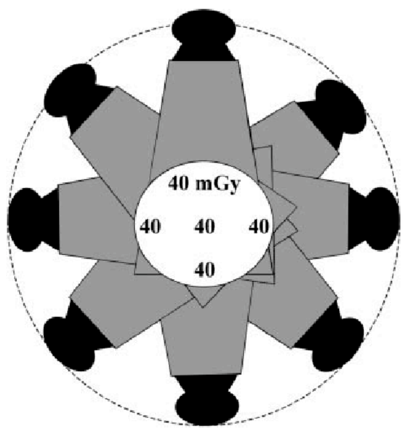
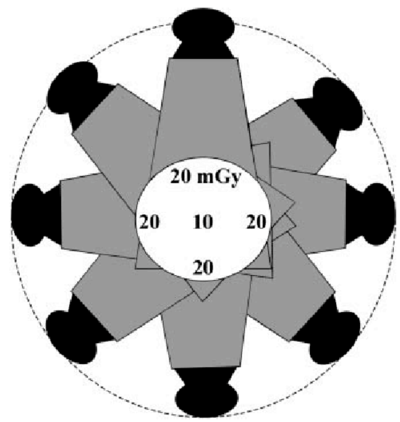
How do we estimate radiation dose from imaging procedures?

Head CT scan



Body CT scan



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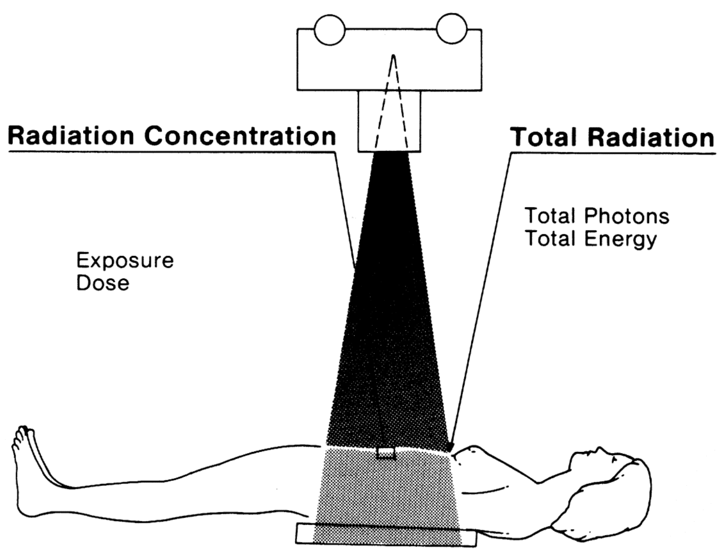
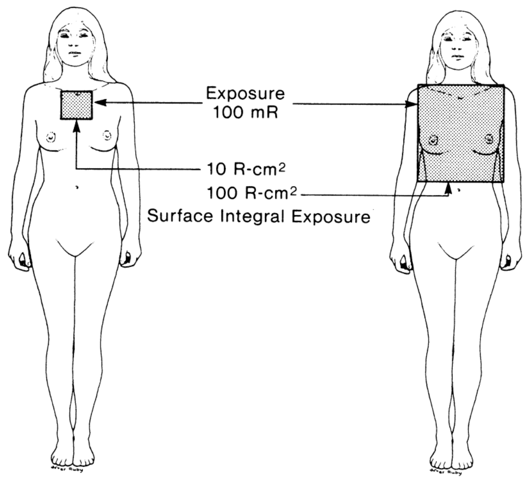
How do we estimate radiation dose from imaging procedures?



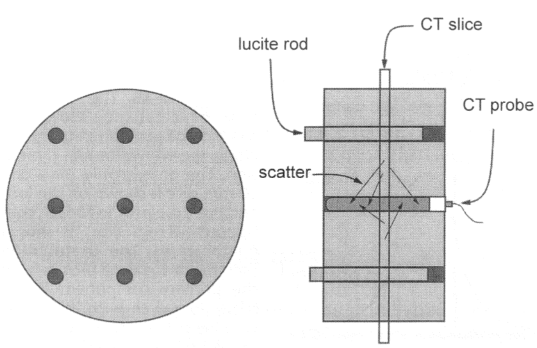
How do we estimate radiation dose from imaging procedures?



In CT, CTDI (dose index) is "radiation concentration"
Effective dose is the "total radiation"

How do we estimate radiation dose from imaging procedures?

Dose distributions in CT measured in phantoms (center & periphery)



Lucite CT dosimetry phantom

How do we estimate radiation dose from imaging procedures?

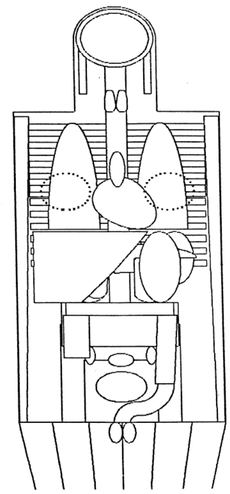
- CTDI parameters quantify CT scanner dose characteristics, not patient doses
- Dose (risk) in CT is best measured by effective dose (E)

Effective Dose

- Proposed by International Commission on Radiological Protection (ICRP Report 60,1990)
- Risk based metric, relating partial body irradiations (individual organ or tissue, limited x-ray field) to uniform whole body irradiation
- The effective dose (E) is the sum of the weighted equivalent doses in all the tissues and organs of the body.
- $E = \Sigma_T W_T H_T$
  - W_T is the weighting factor for tissue T
  - H_T is the individual tissue or organ dose for tissue T

Effective Dose

Organ doses can be measured in phantoms



Effective Dose

- **Sensitive organs (wi = 0.12)**
  - **Red bone marrow**
    Colon
    Lung
    Stomach
- **Moderately sensitive organs (w_i = 0.05)**
  - **Bladder**
    Breast
    Liver
    Esophagus
    Thyroid

A	B	C	D	E	F	G	H	I	J	K	L

ImPACT CT Patient Dosimetry Calculator

Version 0.99w 16/05/05

Scanner Model:			
Manufacturer:	Siemens		
Scanner:	Siemens Volume Zoom, Access		
kV:	120		
Scan Region:	Body		
Data Set	MCSET16	Update Data Set	
Current Data	MCSET16		
Scan range			
Start Position	-4.5	cm	Get From Phantom Diagram
End Position	75.5	cm	
Patient Sex:	m		

Acquisition Parameters:			
Tube current		356	mA
Rotation time		0.5	s
mAs / Rotation		178	mAs
Collimation		10	mm
Slice Width		5	mm
Pitch		1.08	
Rel. CTDI	Look up	1.00	at selected collimation
CTDI (air)	Look up	17.5	mGy/100mAs
CTDI (soft tissue)		18.7	mGy/100mAs
$_{n}CTDI_{w}$	Look up	8.0	mGy/100mAs

Organ	w_T	H_T	$w_T.H_T$
Gonads	0.2	17	3.4
Bone Marrow (red)	0.12	13	1.5
Colon	0.12	16	1.9
Lung	0.12	20	2.4
Stomach	0.12	18	2.2
Bladder	0.05	18	0.92
Breast	0.05	16	0.78
Liver	0.05	18	0.89
Oesophagus (Thymus)	0.05	20	1
Thyroid	0.05	24	1.2
Skin	0.01	10	0.1
Bone Surface	0.01	20	0.2
Remainder 1	0.025	12	0.3
Remainder 2	0.025	12	0.3
		Total Effective Dose (mSv)	17

Remainder Organs	H_T
Adrenals	17
Brain	0.48
Upper Large Intestine	17
Small Intestine	17
Kidney	19
Pancreas	16
Spleen	17
Thymus	20
Uterus	17
Muscle	12

$CTDI_w$ (mGy)	14.2
$CDTI_{vol}$ (mGy)	13.1
DLP (mGy.cm)	1052

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FDG-PET example

- **Dosimetry of individual organs can be measured with low dose scans**
- **Radiation exposure is proportional to the quantity of injected radiopharmaceutical**
- **For a given amount of radiation, damage and risk is higher for pediatric populations**

3.2.1. Absorbed doses: 2-fluoro-2-deoxy-D-glucose (FDG)

^{18}F 109.77 min

	Absorbed dose per unit activity administered (mGy/MBq)				
Organ	Adult	15 years	10 years	5 years	1 year
Adrenals	1.2E−02	1.5E−02	2.4E−02	3.8E−02	7.2E−02
Bladder	1.6E−01	2.1E−01	2.8E−01	3.2E−01	5.9E−01
Bone surfaces	1.1E−02	1.4E−02	2.2E−02	3.5E−02	6.6E−02
Brain	2.8E−02	2.8E−02	3.0E−02	3.4E−02	4.8E−02
Breast	8.6E−03	1.1E−02	1.8E−02	2.9E−02	5.6E−02
Gall bladder	1.2E−02	1.5E−02	2.3E−02	3.5E−02	6.6E−02
GI-tract					
Stomach	1.1E−02	1.4E−02	2.2E−02	3.6E−02	6.8E−02
SI	1.3E−02	1.7E−02	2.7E−02	4.1E−02	7.7E−02
Colon	1.3E−02	1.7E−02	2.7E−02	4.0E−02	7.4E−02
(ULI	1.2E−02	1.6E−02	2.5E−02	3.9E−02	7.2E−02)
(LLI	1.5E−02	1.9E−02	2.9E−02	4.2E−02	7.6E−02)
Heart	6.2E−02	8.1E−02	1.2E−01	2.0E−01	3.5E−01
Kidneys	2.1E−02	2.5E−02	3.6E−02	5.4E−02	9.6E−02
Liver	1.1E−02	1.4E−02	2.2E−02	3.7E−02	7.0E−02
Lungs	1.0E−02	1.4E−02	2.1E−02	3.4E−02	6.5E−02
Muscles	1.1E−02	1.4E−02	2.1E−02	3.4E−02	6.5E−02
Oesophagus	1.1E−02	1.5E−02	2.2E−02	3.5E−02	6.8E−02
Ovaries	1.5E−02	2.0E−02	3.0E−02	4.4E−02	8.2E−02
Pancreas	1.2E−02	1.6E−02	2.5E−02	4.0E−02	7.6E−02
Red marrow	1.1E−02	1.4E−02	2.2E−02	3.2E−02	6.1E−02
Skin	8.0E−03	1.0E−02	1.6E−02	2.7E−02	5.2E−02
Spleen	1.1E−02	1.4E−02	2.2E−02	3.6E−02	6.9E−02
Testes	1.2E−02	1.6E−02	2.6E−02	3.8E−02	7.3E−02
Thymus	1.1E−02	1.5E−02	2.2E−02	3.5E−02	6.8E−02
Thyroid	1.0E−02	1.3E−02	2.1E−02	3.5E−02	6.8E−02
Uterus	2.1E−02	2.6E−02	3.9E−02	5.5E−02	1.0E−01
Remaining organs	1.1E−02	1.4E−02	2.2E−02	3.4E−02	6.3E−02
Effective dose (mSv/MBq)	**1.9E−02**	**2.5E−02**	**3.6E−02**	**5.0E−02**	**9.5E−02**

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Image Gently℠

- Initiative of the Alliance for Radiation Safety in Pediatric Imaging
- Goal: change practice by increasing awareness of opportunities to lower radiation dose in the imaging of children
- Pause and child-size the technique, use the lowest Pulse rate possible. Consider ultrasound or MRI when possible.

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Image Wisely™

- Awareness program of the American College of Radiology, the Radiological Society of North America, the American Association of Physicists in Medicine, and the American Society of Radiologic Technologists.
- Image Wisely's objective is to encourage practitioners to avoid unnecessary ionizing radiation scans and to use the lowest optimal radiation dose for necessary studies.

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Radiation Dose Calculator

- The American College of Radiology (ACR) and the International Atomic Energy Agency (IAEA) both recommend hospitals monitor radiation exposure
- Calculator allows to track imaging history and estimate risk

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DFCI Radiation Safety Committee dose spreadsheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Data Entry Fields		DFCI Nuclear Medicine Procedures										Calculated Values		
2	Number of Scans in Year 1	Number of Scans in All Years	Scan	Isotope	Injected Activity (mCi)	Injected Activity (MBq)	Eff Dose per Unit Activity (mSv/MBq)	Eff Dose per Unit Activity (mSv/mCi)	Effective Dose (mSv)	Effective Dose (Rem)	Effective Dose (rem)	Reference	Effective Dose in Year 1	Effective Dose in All Years	
3			Bone	Tc-99m-MDP	25	925	0.008	0.296	7.4	0.74	0.75	ICRP 53	0	0	
4			Lung Perfusion	Tc-99m-MAA	5	185	0.011	0.407	2.035	0.2035	0.2	ICRP 80	0	0	
5			Ventilation	Xe-133 gas	40	1480	0.0008	0.0296	1.184	0.1184					
6			RVG (MUGA)	Tc-99m-RBC	25	925	0.007	0.259	6.475	0.6475	0.65	ICRP 80	0	0	
7			GI Bleed	Tc-99m-RBC	25	925	0.007	0.259	6.475	0.6475	0.65	ICRP 80	0	0	
8			Hemangioma	Tc-99m-RBC	25	925	0.007	0.259	6.475	0.6475					
9			IP/Leveen shunt	Tc-99m-MAA	5	185	0.011	0.407	2.035	0.2035	0.2	ICRP 80	0	0	
10				Tc-99m Sulfur Colloid	3	111	0.0019	0.0703	0.2109	0.02109					
11			Catheter Flow Study	Tc-99m Pertechnetate	20	740	0.013	0.481	9.62	0.962					
12			Lymphoscintigram	Tc-99m Sulfur Colloid	0.5	18.5	0.0019	0.0703	0.03515	0.003515					
13			Renal function	Tc-99m MAG3	10	370	0.007	0.259	2.59	0.259					
14				Tc-99m MAG4	10	370									
15			Renal GFR	Tc-99m DTPA	15	555	0.0049	0.1813	2.7195	0.27195					
16			Hepatobiliary	Tc-99m Mebrofenin	6	222	0.017	0.629	3.774	0.3774					
17			Damaged RBC Scan	Tc-99m Damaged RBC	10	370	0.007	0.259	2.59	0.259					
18			Gallium	Ga-67 Citrate	10	370	0.1	3.7	37	3.7	3.7	ICRP 80	0	0	
19			Thallium	TL-201 Chloride	3	111	0.23	8.51	25.53	2.553	2.4	ICRP 80	0	0	
20			I-123 MIBG	I-123 MIBG	10	370	0.013	0.481	4.81	0.481	0.48	ICRP 80	0	0	
21			I-131 MIBG	I-131 MIBG	1	37	0.14	5.18	5.18	0.518	0.53	ICRP 53/8	0	0	
22			Octreoscan	In-111 Somatostatin	6	222	0.054	1.998	11.988	1.1988					
23			Prostascint Scan	In-111 Capromab Pendetide	5	185	0.25	9.25	46.25	4.625					
24				Tc-99m RBC	10	370	0.007	0.259	2.59	0.259					
25				In-111/Tc-99m	5	185									
26			DFCI PET Procedures												
27			FDG PET (only)	F-18 FDG	20	740	0.019	0.703	14.06	1.406	1.4	ICRP 80	0	0	
28			NaF PET (only)	F-18 NaF	20	740	0.027	0.999	19.98	1.998	2	NuReg/CR	0	0	
29			FLT PET (only)	F-18 FLT	10	370	0.031	1.147	11.47	1.147					
30			WB FDG PETCT	F-18 FDG	20	740					2.4	ICRP 80/D	0	0	
31			WB NaF PETCT	F-18 NaF	20	740					3	NuReg/CR	0	0	
32			WB FLT PETCT	F-18 FLT	10	370									
33										Total Effective Dose (rem) for all Nucmed/PET Procedures:			0	0	
34			DFCI Radiology Procedures												
35			Scan	kVp	Effective mAs	Effective mAs	Eff Dose per Unit Activity (mSv/MBq)		Effective Dose (rem)	Reference					
36			Chest x-ray						0.004	ICRP 62	0	0			
37			Mammogram						0.045	ICRP 60	0	0			
38			Bone Densitometry						0.001	ACR/RSNA	0	0			
39			Skeletal Survey						0.018	NRPB-W4	0	0			
40			Head CT	120	360	360			0.9	Kalendar 99	0	0			
41			Chest CT	120	180	180			0.64	Kalendar 99	0	0			
42			Abdomen CT						0.68	Kalendar 99	0	0			
43			Pelvis CT						0.39	Kalendar 99	0	0			
44			CAP CT	120	165	165			1.7	DFCI	0	0			
45			CT-guided biopsy						0.8	Br J Radiol. 200	0	0			
46										Total Effective Dose (rem) for all Radiology Procedures:	0	0			
47										Total Effective Dose (rem) for all Nucmed/PET and Radiology Procedures:	0	0			
48										Equivalent to Number of Years of Background Radiation:	0.0	0.0			
49										Equivalent to Number of Years of Maximum Annual Occupational Exposure:	0.0	0.0			
50															
51															

◇	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Data Entry Fields		DFCI Nuclear Medicine Procedures										Calculated Values		
2	Number of Scans in Year 1	Number of Scans in All Years	Scan	Isotope	Injected Activity (mCi)	Injected Activity (MBq)	Eff Dose per Unit Activity (mSv/MBq)	Eff Dose per Unit Activity (mSv/mCi)	Effective Dose (mSv)	Effective Dose (Rem)	Effective Dose (rem)	Reference	Effective Dose in Year 1	Effective Dose in All Years	
3			Bone	Tc-99m-MDP	25	925	0.008	0.296	7.4	0.74	0.75	ICRP 53	0	0	
4			Lung Perfusion	Tc-99m-MAA	5	185	0.011	0.407	2.035	0.2035	0.2	ICRP 80	0	0	
5			Ventilation	Xe-133 gas	40	1480	0.0008	0.0296	1.184	0.1184					
6			RVG (MUGA)	Tc-99m-RBC	25	925	0.007	0.259	6.475	0.6475	0.65	ICRP 80	0	0	
7			GI Bleed	Tc-99m-RBC	25	925	0.007	0.259	6.475	0.6475	0.65	ICRP 80	0	0	
8			Hemangioma	Tc-99m-RBC	25	925	0.007	0.259	6.475	0.6475					
9			IP/Leveen shunt	Tc-99m-MAA	5	185	0.011	0.407	2.035	0.2035	0.2	ICRP 80	0	0	
10				Tc-99m Sulfur Colloid	3	111	0.0019	0.0703	0.2109	0.02109					
11			Catheter Flow Study	Tc-99m Pertechnetate	20	740	0.013	0.481	9.62	0.962					
12			Lymphoscintigram	Tc-99m Sulfur Colloid	0.5	18.5	0.0019	0.0703	0.03515	0.003515					
13			Renal function	Tc-99m MAG3	10	370	0.007	0.259	2.59	0.259					
14				Tc-99m MAG4	10	370									
15			Renal GFR	Tc-99m DTPA	15	555	0.0049	0.1813	2.7195	0.27195					
16			Hepatobiliary	Tc-99m Mebrofenin	6	222	0.017	0.629	3.774	0.3774					
17			Damaged RBC Scan	Tc-99m Damaged RBC	10	370	0.007	0.259	2.59	0.259					
18			Gallium	Ga-67 Citrate	10	370	0.1	3.7	37	3.7	3.7	ICRP 80	0	0	
19			Thallium	TL-201 Chloride	3	111	0.23	8.51	25.53	2.553	2.4	ICRP 80	0	0	
20			I-123 MIBG	I-123 MIBG	10	370	0.013	0.481	4.81	0.481	0.48	ICRP 80	0	0	
21			I-131 MIBG	I-131 MIBG	1	37	0.14	5.18	5.18	0.518	0.53	ICRP 53/8(	0	0	
22			Octreoscan	In-111 Somatostatin	6	222	0.054	1.998	11.988	1.1988					
23			Prostascint Scan	In-111 Capromab Pendetide	5	185	0.25	9.25	46.25	4.625					
24				Tc-99m RBC	10	370	0.007	0.259	2.59	0.259					
25				In-111/Tc-99m	5	185									
26			DFCI PET Procedures												
27			FDG PET (only)	F-18 FDG	20	740	0.019	0.703	14.06	1.406	1.4	ICRP 80	0	0	
28			NaF PET (only)	F-18 NaF	20	740	0.027	0.999	19.98	1.998	2	NuReg/CR	0	0	
29			FLT PET (only)	F-18 FLT	10	370	0.031	1.147	11.47	1.147					
30			WB FDG PETCT	F-18 FDG	20	740					2.4	ICRP 80/D	0	0	
31			WB NaF PETCT	F-18 NaF	20	740					3	NuReg/CR	0	0	
32			WB FLT PETCT	F-18 FLT	10	370									
33						Total Effective Dose (rem) for all Nucmed/PET Procedures:							0	0	

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DFCI Radiology Procedures									
Scan	kVp	Effective mAs	Effective mAs	Eff Dose per Unit Activity (mSv/MBq)		Effective Dose (rem)	Reference		
Chest x-ray						0.004	ICRP 62	0	0
Mammogram						0.045	ICRP 60	0	0
Bone Densitometry						0.001	ACR/RSNA	0	0
Skeletal Survey						0.018	NRPB-W4	0	0
Head CT	120	360	360			0.9	Kalendar 99	0	0
Chest CT	120	180	180			0.64	Kalendar 99	0	0
Abdomen CT						0.68	Kalendar 99	0	0
Pelvis CT						0.39	Kalendar 99	0	0
CAP CT	120	165	165			1.7	DFCI	0	0
CT-guided biopsy						0.8	Br J Radiol. 200	0	0
		Total Effective Dose (rem) for all Radiology Procedures:						0	0
		Total Effective Dose (rem) for all Nucmed/PET and Radiology Procedures:						0	0
		Equivalent to Number of Years of Background Radiation:						0.0	0.0
		Equivalent to Number of Years of Maximum Annual Occupational Exposure:						0.0	0.0

Linear No Threshold Model

- Assume linear relationship between radiation exposure and the risk of cancer
- Assumes that any exposure, regardless of how low, increases risk of cancer
- Greater lifetime risk for exposure at younger age due to greater sensitivity and longer lifespan to potentially develop cancer

BEIR VII

Table 1: Lifetime Attributable Risk of Cancer from Exposure to Radiation

Number of cases per 100,000 persons exposed to a single dose of 0.1 Gy

Age at Exposure	Male	Percent	Female	Percent
0	2563	2.56%	4777	4.78%
5	1816	1.82%	3377	3.38%
10	1445	1.45%	2611	2.61%
15	1182	1.18%	2064	2.06%
20	977	0.98%	1646	1.65%
30	686	0.69%	1065	1.07%
40	648	0.65%	886	0.89%
50	591	0.59%	740	0.74%
60	489	0.49%	586	0.59%
70	343	0.34%	409	0.41%
80	174	0.17%	214	0.21%

Adapted from the National Research Council. Health risks from exposure to low levels of ionizing radiation. BEIR VII Phase 2. Washington, DC: National Academies Press; 2006.

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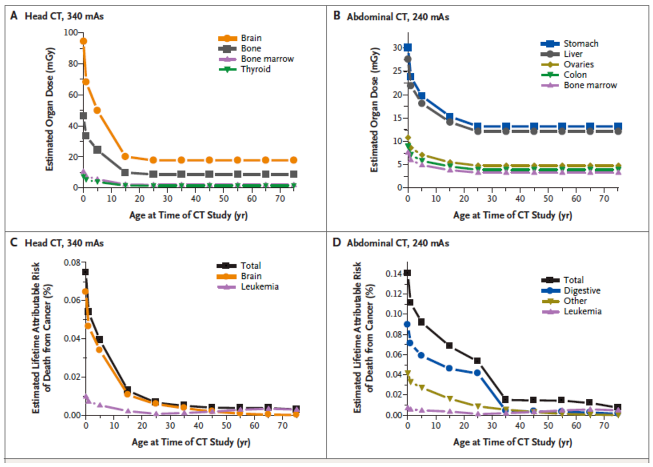
Brenner and Hall



Estimated Organ Doses and Lifetime Cancer Risks from Typical Single CT Scans of the Head and the Abdomen

N Engl J Med 2007;357:2277-84

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Incidents of overexposure

Doctors 'Shocked' by Radiation Overexposure at Cedars-Sinai

Medical Scans Continue Increasing Our Exposure to Radiation, Experts Say

BY RADHA CHITALE
ABC NEWS MEDICAL UNIT
Oct. 13, 2009

abc NEWS
15 COMMENTS

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Doctors have expressed outrage and concern for the unsuspecting patients who received eight times the normal dose of radiation during a specific type of brain scan at Cedars-Sinai Medical Center in Los Angeles.

ABC News Photo Illustration

Hospital officials say a computer resetting error caused radiation overdoses for 206 patients who underwent CT scans at Cedars-Sinai Medical Center in Los Angeles.

The overdose was discovered when a patient reported lost patches of hair following a CT scan.

The error, which Cedars-Sinai attributed to a "misunderstanding" about an incorrectly programmed CT machine, in a statement released Oct. 12, remained unchecked for 18 months, involved 206 people, and exacerbated existing concerns that patients nationwide are being exposed to excess radiation during medical testing.

"To me, even as a professional, this is a fairly shocking story. These patients received 8-10 times the normal dose for a head CT and probably reached their allowable radiation exposure for the year at a single test," said Dr. James Slater, associate professor of cardiology at the NYU Langone Medical Center. "The fact this error occurred and went undetected for 18 months at a well regarded medical [institution] is rather unbelievable."

Incidents of overexposure

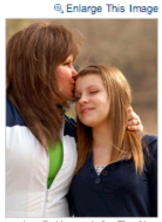
NY times

West Virginia Hospital Overradiated Brain Scan Patients, Records Show

By WALT BOGDANICH
Published: March 5, 2011

A large West Virginia hospital seriously overradiated patients suspected of having strokes with CT scans for more than a year after similar episodes prompted federal officials to alert hospitals nationwide to be especially careful when using those types of scans, interviews and documents show.

Enlarge This Image



Jon C. Hancock for The New York Times

Marcie Iseli and one of her children, Whitley.

Multimedia

Graphic

The patients, at Cabell Huntington Hospital in Huntington, W.Va., were overdosed with radiation until late November, records show, even after the Food and Drug Administration had publicly issued its final report on hundreds of overdoses involving brain scans at other hospitals and the errors had been discussed publicly in Congress and by state officials and professional organizations.

Federal records indicate that Cabell knew of some of the overdoses for three months, but it did not disclose them publicly until The New York Times called the hospital for comment late last week. Within hours, the hospital issued a news release that was picked up by the local media.

Charles Shumaker, a hospital spokesman, declined to say how many patients were overdosed, why the mistakes occurred or whether any hospital employees were disciplined as a result.

But Dr. Rebecca Smith-Bindman, a radiology professor who has testified before Congress about the need for more controls over CT scans, called the dosage report for one Huntington patient — provided to her by The Times — "grossly and unacceptably abnormal."

Who is at risk?

- **Patient / research subject**
- **General public**
- **Workers**
  - **Imaging and radiation oncology physicians**
  - **Technologists and imaging staff**
  - **Flight staff**

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How to reduce exposure?

- **Time**
- **Distance**
- **Shielding (room and/or personal)**

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How do we protect them?

- **Patient / research subject**
  - Departmental safety policies and screening procedures
  - IRB
  - Radiation Safety Committee
  - Radioactive Drug Research Committee
  - Regulatory oversight (Joint Commission, DPH, FDA)
- **General public**
  - Shielding of exam rooms from magnetic fields and radiation
  - Regulated transport/release of radioactive materials
- **Workers**
  - Training and monitoring requirements
  - Annual radiation exposure limits
  - ALARA policies

ALARA

- It is the guiding principle in radiation protection
- Radiation exposure should always be …

As
Low
As
Reasonably
Achievable

How to eliminate unnecessary radiation?

- Tracking of exams (electronic medical records)
- Appropriateness criteria
- Alternative methods of assessment (ultrasound, MRI)

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Radiation Safety Protocol Screening Form

- All research use of radiation must be approved by institutional Radiation Safety Committee
- Screening form allows the RSC to
  - Determine whether there is research use of radiation
  - Estimate the radiation dose to patient
  - Determine if use of radiation is appropriate and safe
  - Provide risk statement for consent form

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DF/HCC Radiation Risk Statement

"This research study involves exposure to radiation from *two additional PET/CT scans*. Please note that this radiation exposure is not necessary for your medical care but is required to obtain the desired research information. From participating in this study, the maximum amount of additional radiation your body will be exposed to in one year is *less than what a person performing your imaging scans is allowed to receive in one year*. There is thought to be an increased long term risk of cancer associated with radiation."

Additional Resources

- Institution Radiation Safety Office
- Institution Departments of Radiology/Nuclear Medicine
- Havard Catalyst Imaging Consortium
  (http://catalyst.harvard.edu/services/imagingconsulting.html)
- jeffrey_yap@dfci.harvard.edu

References

- http://www.xrayrisk.com/
- http://www.pedrad.org/associations/5364/ig/
- http://www.imagewisely.org/
- Brenner and Hall:
  http://www.nejm.org/doi/pdf/10.1056/NEJMra072149

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Acknowledgements

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NIH UL1 RR 025758

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