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# Radiation Dosimetry and Cancer risks of Imaging

**Jeffrey T.Yap, PhD**
Senior Diagnostic Physicist, Department of Imaging, DFCI
Assistant Professor of Radiology, Harvard Medical School
Director of Education, Harvard Catalyst Imaging Consortium
**Valerie Humblet, PhD**
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<br>Randy Gollub, Co-Director<br>Gordon J. Harris, Consultant<br>William Hanlon, Consultant |
| Beth Israel Deaconess Medical Center | Robert Lenkinski, Consultant<br>Ivan Pedrosa, Consultant |
| BWH BRIGHAM AND WOMEN'S HOSPITAL A Teaching Affiliate of Harvard Medical School | Clare Tempany, Consultant<br>Ron Kikinis, Consultant<br>Charles Guttmann, Consultant<br>Todd Perlstein, Consultant<br>Gordon Williams, PI for CTSC Translational Technologies |
| Children's Hospital Boston The Hospital for Children | Stephan Voss, Consultant<br>Simon Warfield, Consultant |
| DANA-FARBER CANCER INSTITUTE | Annick D. Van den Abbeele, Consultant<br>Jeffrey Yap, Consultant, Director of Education |
| HARVARD CATALYST THE HARVARD CLINICAL AND TRANSLATIONAL SCIENCE CENTER | Valerie Humblet, Imaging Liaison<br>Yong Gao, Imaging Informatics Architect |



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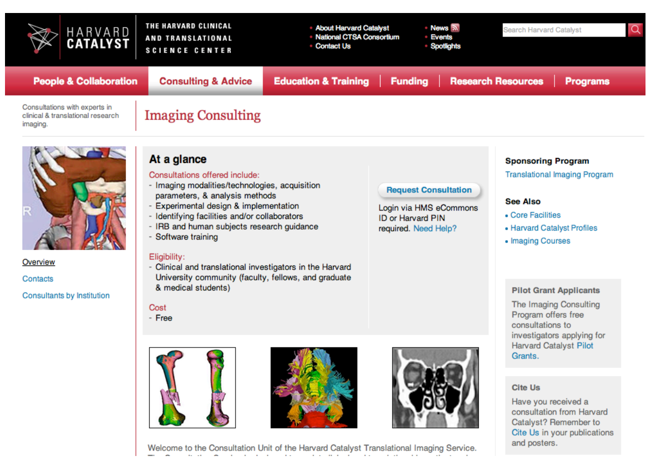
# Harvard Catalyst Imaging Consortium

**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

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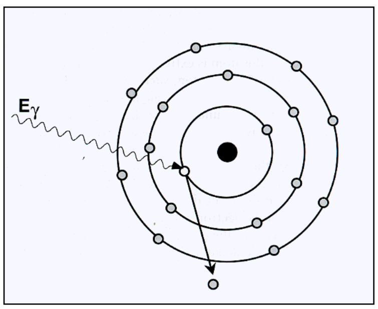
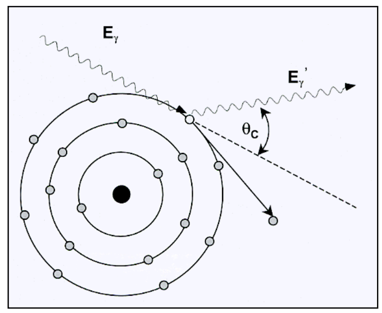
## Definition of Ionizing Radiation

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

Photoelectric effect




Compton scattering

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## 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

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## Imaging modalities that use *ionizing* radiation

- **Radiology**
  - X-ray
  - Dual Energy Xray Absorptiometry (DEXA)
  - 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)

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## 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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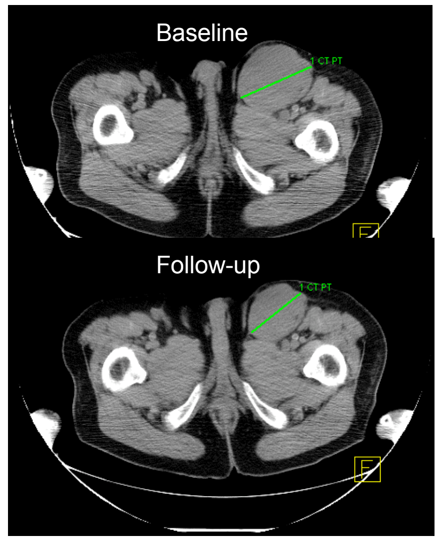
## X-ray Computed Tomography (CT)

- **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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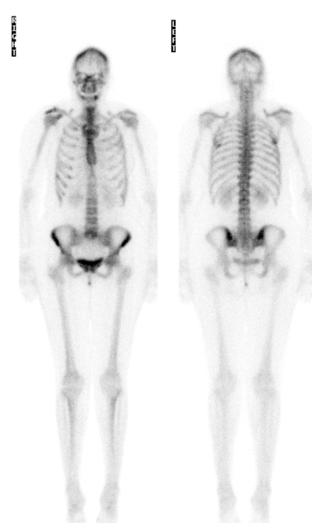
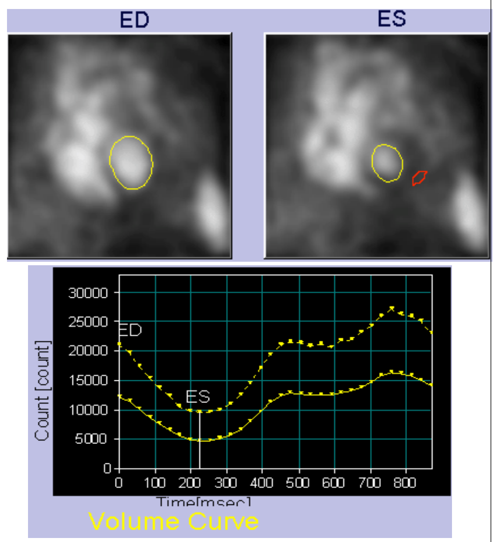
## Bone Scintigraphy (Bone scan)

- **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)**



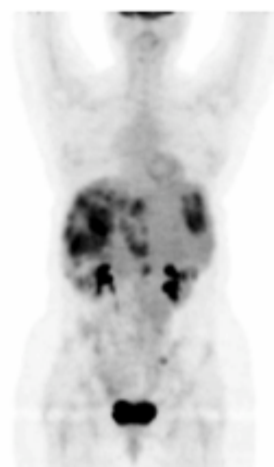
## RVG/MUGA scan

- Can detect wall motion abnormalities
- Estimate cardiac ejection fraction
- Used in screening for trial eligibility
- Performed during or after treatment for safety monitoring (cardiotoxicity)




## 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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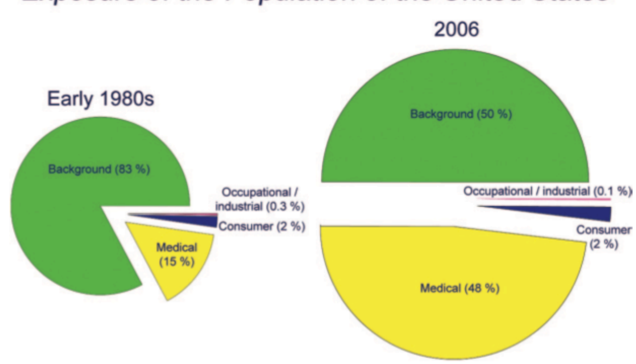
## Increase in radiation exposure

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 |

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## 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)**

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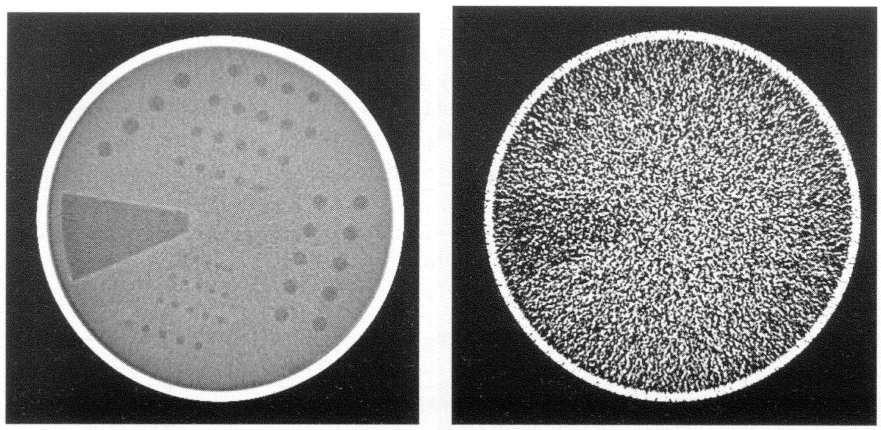
## Why increase in dose?

**Dose is related to image quality**

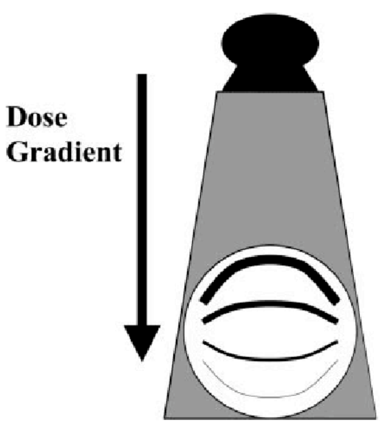
## Why increase in dose?

High dose scan | Low dose scan



## How do we estimate radiation dose from imaging procedures?

# Conventional radiography




x-ray skin dose
2 mGy/0.2 rad

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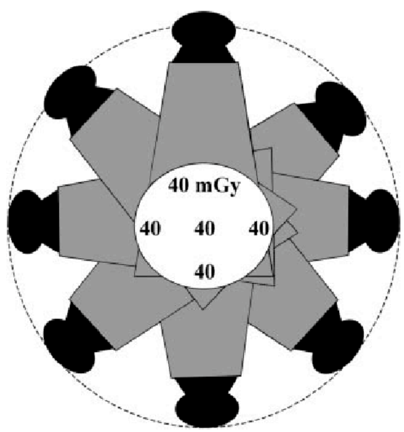
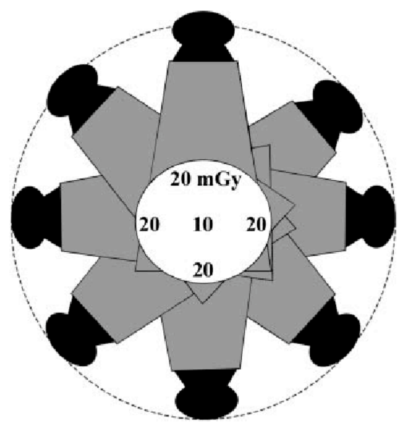
## How do we estimate radiation dose from imaging procedures?

### Head CT scan




### Body CT scan

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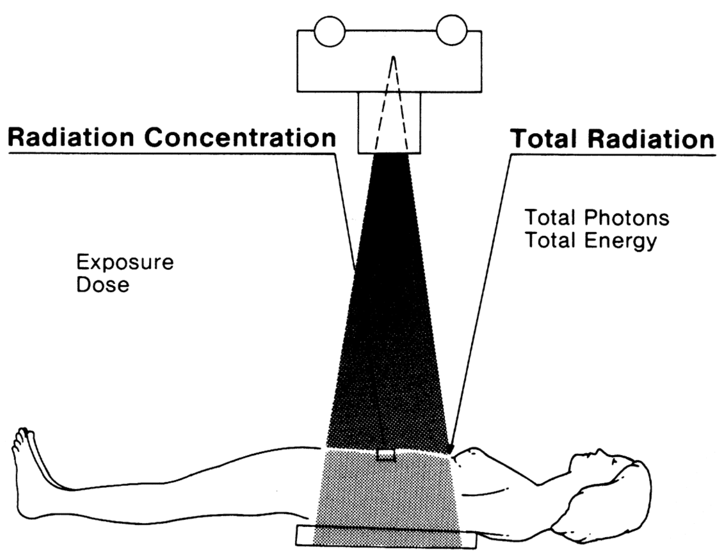
## How do we estimate radiation dose from imaging procedures?



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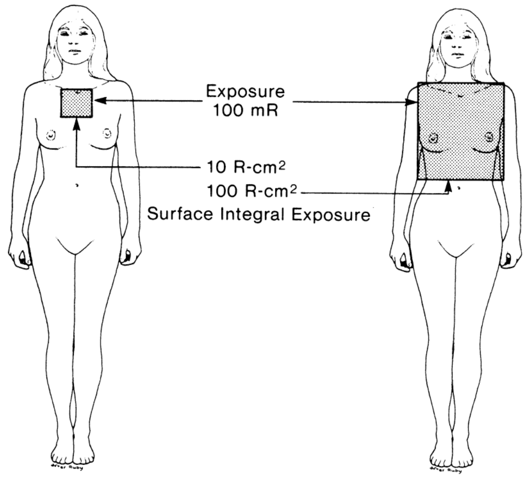
## How do we estimate radiation dose from imaging procedures?




**In CT, CTDI is "radiation concentration"**
**Effective dose is the "total radiation"**

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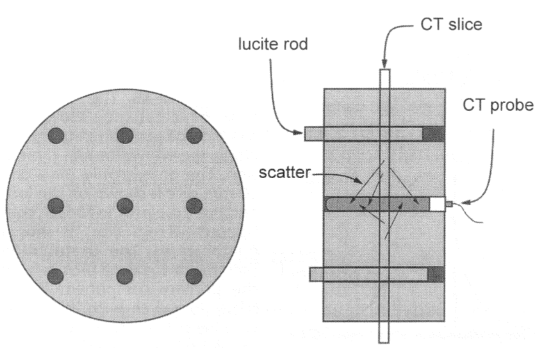
## How do we estimate radiation dose from imaging procedures?

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




Lucite CT dosimetry phantom

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## 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)**

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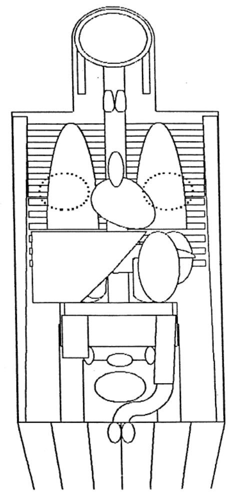
## Effective Dose

- **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

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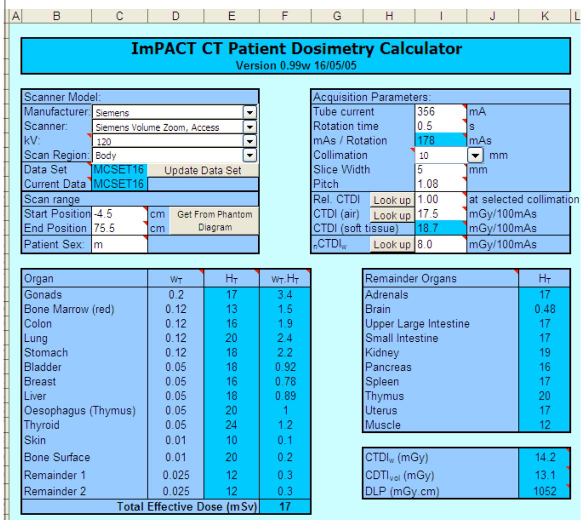
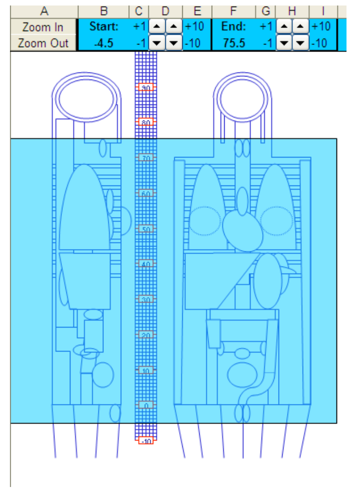
# Effective Dose Calculation in CT

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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** |

## 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.


## 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 RSC 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 | | | | | | | | | | | | | | | |

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## 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

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## 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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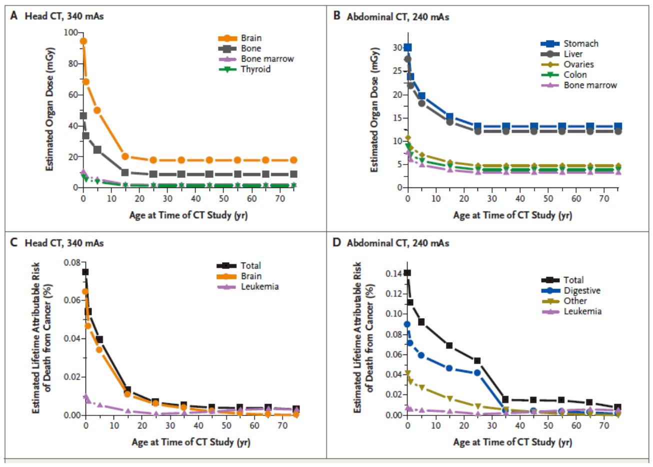
# Brenner and Hall




**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

abcNEWS
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."

The New York Times | Health

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## 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.

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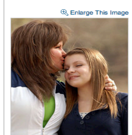


Jon C. Hancock for The New York Times
Marcie Iseli and one of her children, Whitley.

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.

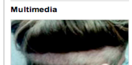
Federal records indicate that Cabell knew of some of the overdoses for three months, but it did not disclose them publicly until The New York Times called the hospital for comment late last week. Within hours, the hospital issued a news release that was picked up by the local media.

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."

Richard A. Patterson, a Los Angeles lawyer who is representing patients who were overradiated at other hospitals, said he and his associates represent at least 20 patients at Cabell who were sent letters from the hospital saying they had received too much radiation.

Multimedia



Graphic
Radiation Overdoses Despite F.D.A. Warnings

Audio & Photos
The Mark of an Overdose

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## 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

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## ALARA

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

**As**
**Low**
**As**
**Reasonably**
**Achievable**

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## 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

## 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

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## 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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