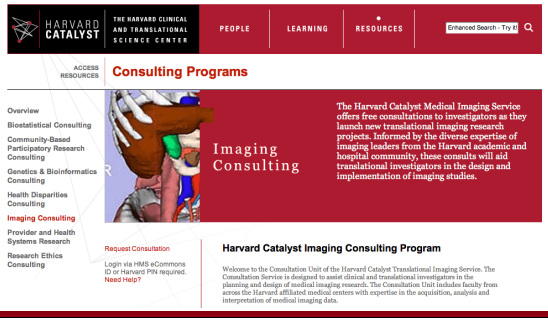
Benefits and Risks of Cancer Imaging

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

http://catalyst.harvard.edu/services/imagingconsulting.html



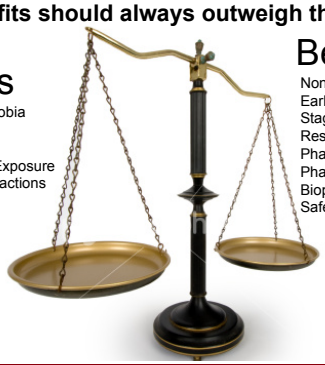
Objectives

- Understand the benefits of x-ray, CT, ultrasound, MRI, PET/CT, and nuclear medicine imaging
- Learn the risks of imaging contrast materials used in CT, MRI, and ultrasound
- Understand the potential risks of ionizing radiation used in imaging
- Understand the DF/HCC radiation safety protocol screening form and model consent risk statements

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

Benefits of Cancer Imaging

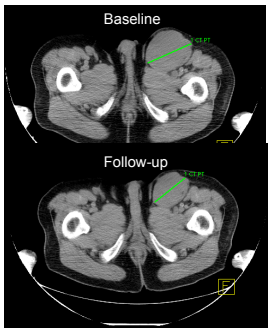
- Tumor detection and/or diagnosis of cancer
- Staging (spread of disease)
- Re-staging (evaluation at end of treatment)
- Monitoring therapy (early or intermediate response assessment)
- Image-guided planning (surgery, radiation therapy)
- Protocol screening
  - Inclusion criteria: e.g., measurable disease
  - Exclusion criteria: e.g., metastasis, cardiac disease
- Safety Monitoring

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)

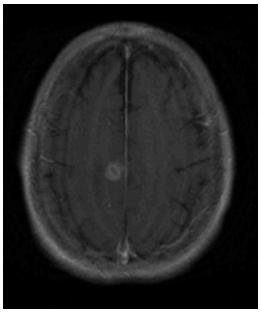
X-ray Computed Tomography (CT)

- 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 trials



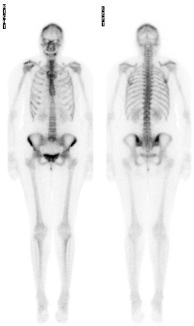
MRI

- High resolution 3-D imaging modality
- Does not use ionizing radiation
- Generally requires longer imaging
- Not be acceptable for some patients (e.g. metal)



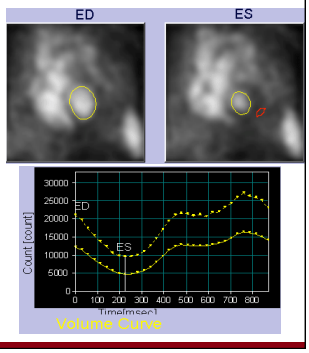
Bone Scintigraphy (Bone scan)

- 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)



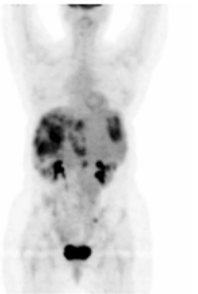
RVG/MUGA scan

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



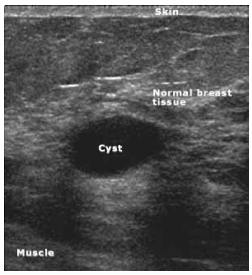
Positron Emission Tomography

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



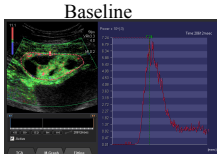
Ultrasound

- Non-invasive and safe
- Uses sound waves (no ionizing radiation)
- Images limited anatomic coverage (not a whole-body technique)
- Useful for biopsy guidance

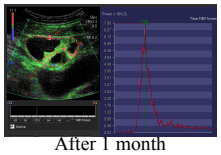


Dynamic contrast enhanced ultrasound

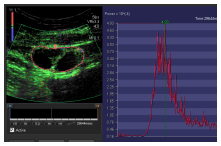
Baseline



After D 7



After 1 month



GIST, Pelvic met
Rx Dasatanib

N Lassau, Institut Gustave Roussy

Contrast Media (Agents)

- Used in CT, MRI, and ultrasound
- Enhance the difference in image intensity between the object of interest (e.g. tumor) and background tissue
- Can be administered intravenous or orally
- Compounds are treated as drugs and require adequate safety procedures.

General risks of injection

- Irritation
- Infection at site of injection
- Extravasation (0.1%–0.9%)
- Air embolism

Risks of Iodinated Contrast

- Iodinated contrast media are frequently used and are safe.
- Reactions, when they occur, are usually mild but may occasionally progress to life-threatening proportions.
- A thorough understanding of the etiology, predisposing factors, symptoms, and management strategies is effective in minimizing the threat posed by these factors.

J Nucl Med Technol 2008; 36:69–74

Risks of Iodinated Contrast

- Anaphylactoid/Idiosyncratic Reactions
  - Mild: skin rash, itching, nasal discharge, nausea, and vomiting
  - Moderate: persistence of mild symptoms, facial or laryngeal edema, bronchospasm, dyspnea, tachycardia, or bradycardia
  - Severe: life- threatening arrhythmias, hypotension, overt bronchospasm, laryngeal edema, pulmonary edema, seizure, syncope, and death

J Nucl Med Technol 2008; 36:69–74

Risks of Iodinated Contrast

- Nonanaphylactoid Reactions
  - Cardiovascular, respiratory, urinary, gastrointestinal, and nervous systems are most commonly affected by physiologic changes produced by contrast media.
  - The symptoms of nonanaphylactoid reactions are warmth, metallic taste, nausea, vomiting, bradycardia, hypotension, vasovagal reactions, neuropathy, and delayed reactions

J Nucl Med Technol 2008; 36:69–74

Risks of Iodinated Contrast

- Delayed Reactions:1 hr-7 days after injection (approximately 2% of patients)
  - Common flu-like symptoms (fever, chills, rashes, pruritus, and nausea).
  - Less-frequent manifestations are parotitis, joint pain, and depression. sd
- Contrast-Induced Nephrotoxicity
  - Estimated incidence of 2-7%
  - Multiple risk factors (e.g. renal disease)
  - Requires thorough screening

J Nucl Med Technol 2008; 36:69–74

Ultrasound contrast: microbubbles

- FDA approved agent used in cardiology (Lantheus: Definium)
- Active clinical trials in U.S. to evaluate agent currently used clinically in Europe (Bracco: Sonovue)
- Previous FDA black box restriction for cardiac incidents

Sonovue safety profile/risk

- Headache, warmth, flushing
- Nausea, chills, chest pain
- 5 deaths/2 million doses = 1/400,000
  - Echocardiographic (unstable angina): 3
  - 9 hour post contrast: 1
  - Anaphylactoid rxn: 1
- MRI/CT death: 1-3/100,000 (0.002%)

MRI Risks

- Noise
- Claustrophobia
- Strong magnetic fields
- Gadolinium contrast
  - Allergic reactions
  - Nephrogenic systemic fibrosis (NSF)

MRI Safety Lecture available through Harvard Catalyst Imaging Consortium

Radiation risks

- Very high dose radiation can have immediate tissue damage and risk of future cancer
- Low dose radiation may have increased long term risk of cancer
- Most risk models are based on survivors of catastrophic radiation incidents (atom bomb, Chernobyl)

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.

Who is at risk?

- Patient / research subject
- General public
- Workers
  - Physicians
  - Technologists

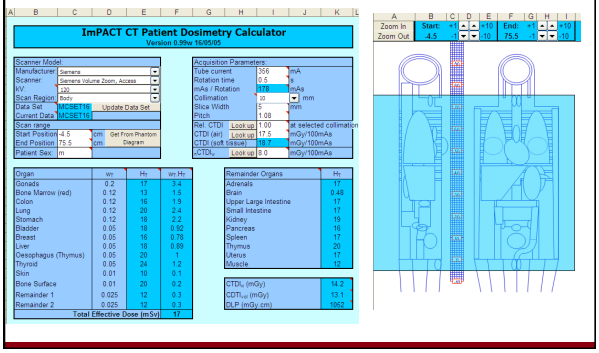
How do we protect them?

- 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 (As Low As Reasonably Achievable)

Effective Dose (E)

- 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 Calculation in CT



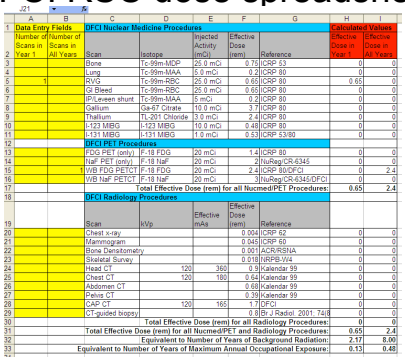
Radiation Safety Protocol Screening Form

- 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

DANA-FARBER CANCER INSTITUTE

HARVARD MEDICAL SCHOOL

DFCI RSC dose spreadsheet



	A	B	C	D	E	F	G	H	I
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)	Effective Dose (rem)	Reference	Effective Dose in Year 1	Effective Dose in All Years
3			Bone	Tc-99m-MDP	25.0 mCi	0.75	CRP 53	0	0
4			Lung	Tc-99m-MAA	5.0 mCi	0.2	CRP 80	0	0
5	1		RVG	Tc-99m-RBC	25.0 mCi	0.65	CRP 80	0.65	0
6			GI Bleed	Tc-99m-RBC	25.0 mCi	0.65	CRP 80	0	0
7			IP/Lween shunt	Tc-99m-MAA	5 mCi	0.2	CRP 80	0	0
8			Gallium	Ga-67 Citrate	10.0 mCi	3.7	CRP 80	0	0
9			Thallium	Tl-201 Chloride	3.0 mCi	2.4	CRP 80	0	0
10			I-123 MIBG	I-123 MIBG	10.0 mCi	0.48	CRP 80	0	0
11			I-131 MIBG	I-131 MIBG	1.0 mCi	0.53	CRP 53/80	0	0
12			DFCI PET Procedures						
13			FDG PET (only)	F-18 FDG		20 mCi	1.4	CRP 80	0	0
14			NaF PET (only)	F-18 NaF		20 mCi	2	NuReg/CR-6345	0	0
15	1		WB FDG PETCT	F-18 FDG		20 mCi	2.4	CRP 80/DFCI	0	2.4
16			WB NaF PETCT	F-18 NaF		20 mCi	3	NuReg/CR-6345/DFCI	0	0
17				Total Effective Dose (rem) for all Nucmed/PET Procedures:				0.65	2.4
18			DFCI Radiology Procedures						
19			Scan	kVp		Effective mAs	Effective Dose (rem)	Reference		
20			Chest x-ray				0.004	CRP 62	0	0
21			Mammogram				0.045	CRP 60	0	0
22			Bone Densitometry				0.001	ACR/RSNA	0	0
23			Skeletal Survey				0.018	NRPB-W4	0	0
24			Head CT		120	360	0.9	Kalendar 99	0	0
25			Chest CT		120	180	0.64	Kalendar 99	0	0
26			Abdomen CT				0.68	Kalendar 99	0	0
27			Pelvis CT				0.39	Kalendar 99	0	0
28			CAP CT		120	165	1.7	DFCI	0	0
29			CT-guided biopsy				0.8	Br J Radiol. 2001; 74(8	0	0
30						Total Effective Dose (rem) for all Radiology Procedures:			0	0
31				Total Effective Dose (rem) for all Nucmed/PET and Radiology Procedures:				0.65	2.4
32						Equivalent to Number of Years of Background Radiation:		2.17	8.00
33						Equivalent to Number of Years of Maximum Annual Occupational Exposure:		0.13	0.48

DANA-FARBER CANCER INSTITUTE

HARVARD MEDICAL SCHOOL

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."

DANA-FARBER CANCER INSTITUTE

HARVARD MEDICAL SCHOOL

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