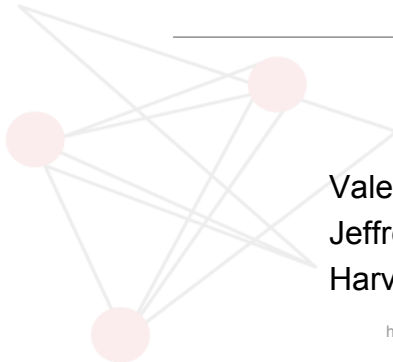




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Benefits and Risks of Imaging



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<http://catalyst.harvard.edu>



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Outline

- **Harvard Catalyst Imaging Consortium**
- **Benefits and Risks of Imaging**
- **References**

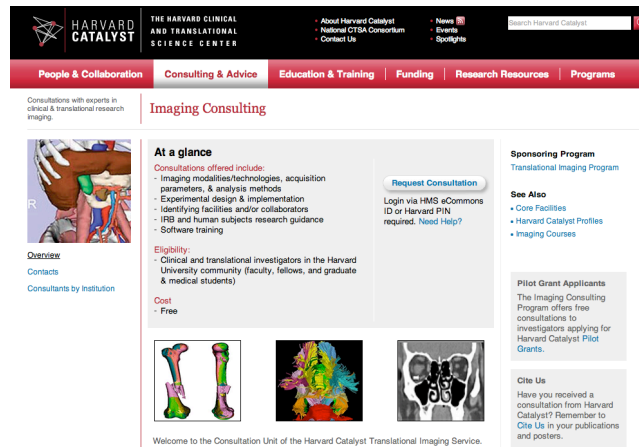
Harvard Catalyst Imaging Consortium

- **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**

Harvard Catalyst Imaging Consortium

 <p>MASSACHUSETTS GENERAL HOSPITAL</p>	<p>Bruce Rosen, Director Randy Gollub, Co-Director Gordon J. Harris, Consultant William Hanlon, Consultant</p>
 <p>Beth Israel Deaconess Medical Center</p>	<p>Robert Lenkinski, Consultant Ivan Pedrosa, Consultant</p>
 <p>BRIGHAM AND WOMEN'S HOSPITAL <small>A Teaching Affiliate of Harvard Medical School</small></p>	<p>Clare Tempany, Consultant Ron Kikinis, Consultant Charles Guttman, Consultant Todd Perlstein, Consultant Gordon Williams, PI for CTSC Translational Technologies</p>
 <p>Children's Hospital Boston <small>The Hospital for Children</small></p>	<p>Stephan Voss, Consultant Simon Warfield, Consultant</p>
 <p>DANA-FARBER CANCER INSTITUTE</p>	<p>Annick D. Van den Abbeele, Consultant Jeffrey Yap, Consultant, Director of Education</p>
 <p>HARVARD CATALYST THE HARVARD CLINICAL AND TRANSLATIONAL SCIENCE CENTER</p>	<p>Valerie Humblet, Imaging Liaison Yong Gao, Imaging Informatics Architect</p>

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



The screenshot shows the Harvard Catalyst Imaging Consulting website. At the top, there is a navigation bar with links for 'About Harvard Catalyst', 'National CTSA Consortium', 'Contact Us', 'News', 'Events', and 'Spotlights'. Below this is a secondary navigation bar with 'People & Collaboration', 'Consulting & Advice', 'Education & Training', 'Funding', 'Research Resources', and 'Programs'. The main content area is titled 'Imaging Consulting' and features a 'Request Consultation' button. It lists services offered, eligibility criteria, and a 'See Also' section with links to 'Core Facilities', 'Harvard Catalyst Profiles', and 'Imaging Courses'. There are also images of anatomical structures and a 'Cite Us' section at the bottom.

Objectives

- **Understand the benefits and risks of x-ray, CT, MRI, PET, and ultrasound**
- **Learn the risks of imaging contrast materials used in CT, MRI, and ultrasound**
- **Understand the potential risks of ionizing radiation used in imaging**

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

Benefits of Imaging

- **Detection and diagnosis of disease at its earliest, most treatable stages**
- **Staging (spread of disease)**
- **Re-staging (evaluation at end of treatment)**
- **Monitoring therapy (early or intermediate response assessment)**
- **Image-guided planning (surgery, radiation therapy)**
- **Not only improve health outcomes and save lives, but also reduce health care costs**

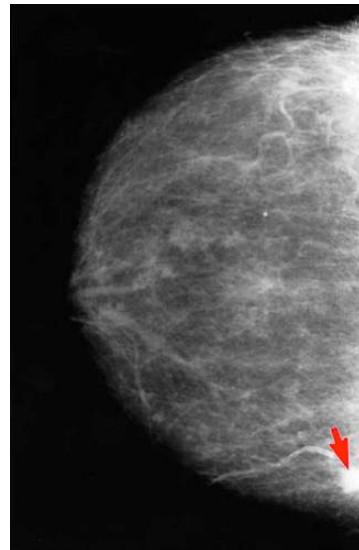
Benefits examples

- **For all cancers, PET scanning allowed to avoid additional tests or procedures 77% of the time. In 36% of cases, it resulted in a physician's decision to alter the patient's course of treatment**
- **Coronary Computed Tomographic Angiography (CCTA) rules out coronary artery disease with over 90% accuracy, saving patients from unnecessary surgery**

<http://www.medicalimaging.org/>

Mammography

- **Uses a low-dose X-ray system to examine breasts**
- **Used to aid in the early detection and diagnosis of breast diseases in women**
- **Only used for detecting locoregional disease (not a whole-body technique)**

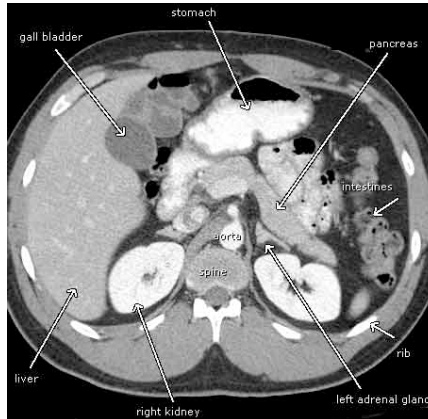


- **Benefits**
 - **Very low radiation dose procedure. X-rays usually have no side effects in the diagnostic range**
 - **High spatial resolution capable of detecting small lesions**

- **Risks**
 - **Radiation: conservative approach**
 - **False Positive: 5 to 15% of screening mammograms require more testing ultimately confirming that no cancer was present (example: deodorant, talcum powder or lotion under arms or on breasts can appear as calcium spots)**

Computed Tomography (CT)

- **Combines special x-ray equipment with sophisticated computers to produce 3D whole body Imaging**
- **Images of internal organs, bones, soft tissue and blood vessels**



Computed Tomography (CT)

- **Ideal for image guidance: biopsy, surgery, radiation**
- **Standard for response assessment in clinical oncology trials**
- **Diagnoses problems such as cancers, cardiovascular disease, infectious disease, appendicitis, trauma and musculoskeletal disorders**

Computed Tomography (CT) Benefits

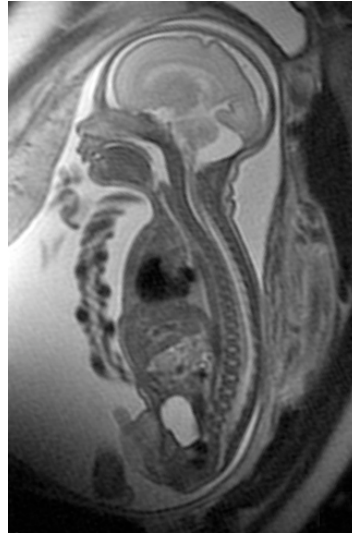
- **High 3D resolution**
- **Ability to image bone, soft tissue and blood vessels all at the same time**
- **Fast and simple; in emergency cases, they can reveal internal injuries and bleeding quickly enough to help save lives**
- **Less sensitive to patient movement than MRI**
- **Can be performed on people with implanted medical device, unlike MRI**

Computed Tomography (CT) Risks

- **Higher radiation dose than planar X-ray**
- **Not recommended for pregnant women (potential risk to the baby)**
- **Nursing mothers should wait for 24 hours after contrast material injection before breast-feeding**
- **Rare risk of serious allergic reaction to contrast materials that contain iodine**
- **Children: CT study only if it is essential for making a diagnosis and should not have repeated CT studies unless absolutely necessary**

Magnetic Resonance Imaging (MRI)

- **Noninvasive, high resolution 3D imaging modality**
- **Uses a powerful magnetic field, radio frequency pulses and a computer to produce detailed pictures of organs, soft tissues, bone and virtually all other internal body structures**



Compendium of fetal MRI, D. Levine

Magnetic Resonance Imaging (MRI) Benefits

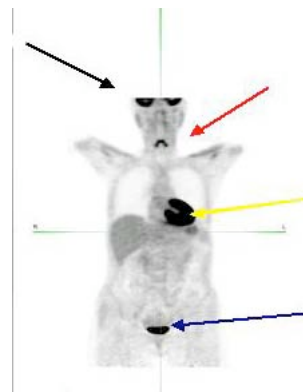
- **Utilize non-ionizing radiation (no cancer risks)**
- **Proven valuable in diagnosing cancer, heart and vascular disease and muscular and bone abnormalities**
- **Enables discovery of abnormalities that might be obscured by bone with other imaging methods**
- **The contrast material is less likely to produce an allergic reaction than the iodine-based contrast materials used for conventional X-rays and CT scanning**

Magnetic Resonance Imaging (MRI) Risks

- **Not acceptable for some patients: implanted metallic medical devices may malfunction or cause problems**
- **Very slight risk of an allergic reaction to contrast material**
- **Risk of Nephrogenic Systemic Fibrosis**
- **Noise, claustrophobia**

Positron Emission Tomography (PET)

- **Nuclear medicine imaging**
- **Functional and molecular imaging modality**
- **Diagnoses many types of cancers, heart disease and certain other abnormalities within the body**
- **Uses injected radioactive material that accumulates in certain area of the body**



Positron Emission Tomography (PET) Benefits

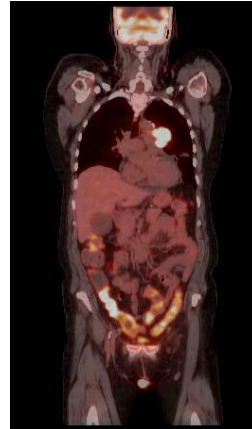
- **Different radiopharmaceuticals used to measure biochemical and pathophysiological properties (blood flow, oxygen use, and sugar (glucose) metabolism)**
- **FDG-PET (most common procedure) can provides unique information: measure of metabolic changes**
- **FDG-PET can detect diseases at earlier stages, since disease processes often begin with functional changes at the cellular level**

Positron Emission Tomography (PET) Risks

- **Exposure to radioactive material, but in low doses considered to be safe**
- **Injection of the radiotracer may cause slight pain and redness**
- **Pregnant or breastfeeding women should discuss the risks and benefits with their doctors before having the tests performed**

PET/CT

- **Combined PET and CT scanner**
- **Provides images that pinpoint the location of abnormal metabolic activity within the body**
- **Accurate: eliminates differences in patient positioning from separate scans**
- **Greater convenience for the patient who undergoes two exams at one sitting**



Ultrasound

- **Uses high-frequency sound waves**
- **No ionizing radiation**
- **Real-time image capture, show structure and movement, as well as blood flow**
- **Not a whole-body technique**
- **Useful for biopsy guidance**



Contrast Enhanced Ultrasound

- **Use of microbubbles (targeted or untargeted) that reflect the US waves.**
- **Applications:**
 - **Organ Edge Delineation**
 - **Blood Volume and Perfusion:**
 - **Inflammation (Crohn's disease, atherosclerosis)**
 - **Cancer (angiogenesis)**

Ultrasound Benefits

- **Noninvasive and usually painless**
- **Widely available, easy-to-use and less expensive than other imaging methods**
- **No ionizing radiation**
- **Gives a clear picture of soft tissues that do not show up well on X-ray images**
- **Preferred imaging modality for the diagnosis and monitoring of pregnant women and their unborn babies**

Ultrasound Risks

- **For standard diagnostic ultrasound there are no known harmful effects on humans**
- **Risks linked to contrast agents discussed later**

Contrast 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 Agents

- **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**

Risks of iodinated Contrast Agents

- **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 Agents

- **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 Agents

- **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.
- **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**

Ultrasound contrast: microbubbles

- **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 reaction: 1
- **MRI/CT death: 1-3/100,000 (0.002%)**

Risks of MRI contrast agents

- **Most commonly used contrast agents are gadolinium-based**
- **Anaphylactic reactions are rare but do occur**
- **Nephrogenic systemic fibrosis (NSF):**
 - Newly discovered disease (1997) associated with the use of Gd-based MRI contrast agents in patients with severe renal disease disorder
 - Characterized by thickening and hardening of the skin and immobility or tightening of the joints
 - Screening for risk factors for kidney disease (> 60 years, diabetes, systemic lupus erythematosus, history of renal disease, multiple myeloma) is crucial

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)**

Radiation risks

- **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 (Biological Effects of Ionizing Radiation)**

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 National Research Council. Health Risks from Exposure to Low Levels of Ionizing Radiation. BEIR VII Phase 2. Washington DC. National Academic Press, 2006

- **Who is at risk:**
 - **Patient / research subject**
 - **General public**
 - **Workers**
 - **Physicians**
 - **Technologists**
 - **Staff**

- **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)**

References

- **Description of procedures, how to prepare for it:**
- <http://www.radiologyinfo.org/>
- <http://www.medicalimaging.org/>

Acknowledgements