Benefits and Risks of Imaging

Valerie Humblet, PhD
Jeffrey T. Yap, PhD
Harvard Catalyst Imaging Consortium

http://catalyst.harvard.edu

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

<table>
<thead>
<tr>
<th>Institution</th>
<th>Members</th>
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</table>
| 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 |
| Brigham and Women's Hospital | Clare Tempany, Consultant
Ron Kikinis, Consultant
Charles Guttmann, Consultant
Todd Perlstein, Consultant
Gordon Williams, PI for CTSC Translational Technologies |
| Children's Hospital Boston | Stephan Voss, Consultant
Simon Warfield, Consultant |
| Dana-Farber Cancer Institute | Annick D. Van den Abbeelee, Consultant
Jeffrey Yap, Consultant, Director of Education |
| Harvard Catalyst | Valerie Humblet, Imaging Liaison
Yong Gao, Imaging Informatics Architect |
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).
Mammography

• 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

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 intravenously 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


• 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

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


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 erythematosis, 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)

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
Radiation risks

• **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

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

• 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.radiologyinfo.org/)
  - [http://www.medicalimaging.org/](http://www.medicalimaging.org/)

Acknowledgements

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