Medical Imaging 101

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Harvard Catalyst Imaging Consortium

http://catalyst.harvard.edu

November 5, 2009

Imaging Consortium Team

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<th>Institution</th>
<th>Members</th>
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<td>Massachusetts General Hospital</td>
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Imaging Consortium Consultation Service

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

MedscapeWire
MRI and CT Ranked the Top Medical Innovations by Physicians
October 11, 2001

New York - Physicians surveyed about the most important innovations of the last 25 years ranked interventions for cardiovascular disease and high-tech scanning devices such as magnetic resonance imaging (MRI) and computed tomography (CT) among the most important. They ranked bone marrow transplantation and the erectile dysfunction drug sildenafil among the least important innovations.

The ranking of the 20 medical innovations in the study are as follows:

1. MRI and CT
2. Bone marrow replacement
3. Balloon angioplasty
4. New minimally invasive approaches
5. Coronary artery bypass graft
6. Proton pump inhibitors and H2 blockers
7. Selective serotonin reuptake inhibitors (SSRIs) and new non-SHRI antidepressants
8. Cancer drug and gene therapy
9. Calafate enemas and colonoscopy
10. Upright endoscopy
11. Ultrasonography and chromoendoscopy
12. Instrumental endoscopy
13. New device for abortion
14. Laparoscopic surgery
15. Nonsteroidal anti-inflammatory drugs and COX-2 inhibitors
16. Cardiovascular devices
17. Fluoroquinolones
18. New lipolytic agents
19. HIV testing and treatment
20. Transfusion
21. Prostate-specific antigen testing
22. Long-acting and local opioid medications
23. Helicobacter pylori testing and treatment
24. Bone densitometry
25. Third-generation cephalosporins
26. Calcium channel blockers
27. Intravenous contrast sedation
28. Sildenafil (Viagra)
29. Non-steroidal anti-inflammatories
30. Bone marrow transplant

Fuchs and Sox, Health Affairs 2001 20(5):30-43
Your patient?

http://www.nlm.nih.gov/research/visible/

X-Ray Fluoroscopy

Computed Tomography

Magnetic Resonance Imaging

Ultrasound Imaging
Advances in Structural MRI Acquisition

- Traditional pulse sequences

- Novel pulse sequence improves subcortical region

Intrinsic MS Information in MRI

Dominik Meier, Wing Wu, Charles Guttmann, Center for Neurological Imaging, BWH
Scale in studying the nervous system

Interact in 3D to enhance data interpretation

Slicer Workshop
November 23, 12 pm
Countway
Matching Image Acquisition to Target Biomarker

Primary outcome measures determine details of acquisition and analysis
All acquisitions must be standardized within &/or across site and time

Definition of a biomarker

• “A characteristic that is objectively measured and evaluated as an indicator of normal biologic processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention.”

Ideal relationship between intervention, disease and surrogate endpoint

• Surrogate is in the only causal pathway of disease and intervention’s entire effect on true clinical outcome is mediated through its effect on the surrogate

What is quantitative imaging?

• Extracting quantitative measurements from medical imaging

Which imaging parameters are quantitative?

- Morphology
  - Volume, 3D techniques
  - Cellularity/density/composition of tissues
- Function
  - Perfusion (DCE-MRI)
  - Metabolic activity (PET)
  - Metabolite concentration (H1 spectroscopy, Na23)
  - Molecule movement, e.g. water molecule (DWI)

Why QI qualifies as a biomarker?

- An ideal biomarker should give a specific and continuous indication of the disease and be quantifiable by using a readily obtainable matrix
- Imaging provides quantifiable parameters noninvasively
Alzheimer's Disease Neuroimaging Initiative

- ADNI Imaging Goals:
  - Link all data at each time point and share data with public
  - Develop technical standards for imaging in longitudinal studies
  - Optimize acquisition and analysis
  - Validate imaging and biomarker data with psychometric and clinical assessments
  - Improve clinical trial methods


ADNI – Biomarkers for AD

- A longitudinal multisite study of elderly people with either mild cognitive impairment (MCI, N=400), Alzheimer’s Disease (AD, N=200) or normal cognition (N=200).
- Data was collected at 55 sites.
- Half of the subjects were imaged using FDG positron emission tomography (PET). All were imaged using MRI on a 1.5T scanner with a structural imaging protocol.
**ADNI – Technical Issues**

- While humans can make sense of images with minor artifacts, this is not usually true of automated processing pipelines.

Therefore:
1. use larger fields-of view and many slices
2. no parallel imaging
3. no partial k-space imaging
4. correct for chemical shift artifacts
5. correct for intensity inhomogeneity

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**Structural localization of function**

Brodmann 1909

Desikan 2009
Automated Freesurfer segmentation output predicts MCI

- Entorhinal cortical thickness
- Hippocampal volume
- Supermarginal gyrus thickness

Desikan, et al Brain, 2009

Clinical Research with vascular ultrasound

Todd Perlstein

Brigham and Women's Hospital
Ultrasound assessed flow mediated vasodilation is an effective means of measuring endothelium-derived nitric oxide

- Endothelium-derived relaxing factor (EDRF) identified 1980
- Nitric oxide (NO) identified as being EDRF in 1986
- NO now recognized as principal determinant of endothelial function and vascular homeostasis
- NO half-life of seconds prevents direct quantification in humans

Vanhoucke PM. ATVB 2009.

- Demonstration that FMD is NO-dependent in 1996. Lieberman E. AJC.

High-resolution ultrasound achieves excellent endothelial imaging

FMD improves with Rituximab therapy in Rheumatoid Arthritis. Kerekes G. Clin Rheum 2009

Standardized protocol completed in < 1 hour

Precise measurement enables small sample size. Donald AE. JACC 2008
Non-invasive determination of atherosclerosis burden: carotid intima-media thickness

- Carotid IMT strongly correlates with CV risk factors
- Standardized protocol completed in < 20 min

Carotid IMT can demonstrate accelerated atherosclerosis in chronic inflammatory diseases

Carotid IMT progression documents benefit of lipid-lowering therapy in patients with coronary artery disease

FDG-PET as an imaging biomarker of metabolic response to Gleevec in GIST patients

Jeffrey Yap, Annick Van den Abbeele

Dana Farber Cancer Institute
Time to Treatment Failure by SUVmax Percent Reduction

Van den Abbeele et al Updated from ASCO 2002

Volumetric Fetal Brain MRI Reconstruction and Processing

Ali Gholipour, Neil I. Weisenfeld, Simon K. Warfield
Computational Radiology Laboratory

Judy A. Estroff, Carol E. Barnewolt, Ellen Grant
Advanced Fetal Care Center

Children’s Hospital Boston
Volumetric Fetal Brain MRI Reconstruction

• Left: pial surface model of a reconstructed fetal brain image; and right: 3D model of tissue segmentations with ventricles highlighted in green
High Leadcount EEG Source Localization for Pediatric Epilepsy Surgical Planning

Damon Hyde, Simon K. Warfield
Computational Radiology Laboratory
Children’s Hospital Boston
Detection of DTI White Matter Abnormalities in Multiple Sclerosis Patients

O. Commowick, P. Fillard, O. Clatz, S.K. Warfield

Children’s Hospital Boston

**Objective:** Detect local and remote damages to the white matter due to MS  
**Method:** Build a reference standard to be compared locally to patients  
**Results:** Abnormalities detected both inside the lesions and around them
3D MR volumetric analysis of prostate cancer: treatment response

Clare Tempany

Brigham and Women’s Hospital

CALGB Study Protocol

Baseline MRI

2 Months Total Androgen Suppression

LHRH Agonist (Lupron)
Anti Androgen (Flutamide)

TUMOR VOLUME 17.84 cc

TUMOR VOLUME 7.8 cc
Dynamic contrast enhanced MRI of prostate cancer

Clare Tempany
Brigham and Women’s Hospital

MaxSlope, Ktrans, Kep, Washout

AIF and tumor kinetic curve
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The Harvard Catalyst Medical Imaging Service offers free consultations to investigators as they launch new translational imaging research projects. Designed for the clinical investigator to help implement imaging in the planning and design of studies, these consultations will aid in bridging translational concepts from the bench to bedside and hospital community. These consultations will aid in overcoming challenges in the design and implementation of imaging studies.
Imaging Consortium wiki


- Medical imaging education and training
- Medical image acquisition, analysis and visualization resources