Hybrid Imaging Systems

Roger Fulton, PhD
Brain and Mind Research Institute, University of Sydney; Westmead Hospital, Sydney

What is Hybrid Imaging?

Hybrid (or multimodality) imaging is the integration of two or more modalities: PET, SPECT, CT, MRI, fMRI, optical, ultrasound, etc with the images being registered in space and time.

Hybrid Imaging Approaches

Serial Hybrid Imaging
- Images acquired separately and fused together by rigid or nonrigid image registration.
- Useful, but prone to registration error due to body deformation, respiratory motion, disease progression.

Integrated Hybrid Imaging
- Simultaneous or near simultaneous acquisition,
- Examples: PET/CT, SPECT/CT, PET/MR, ...
- Better co-registration.

Hybrid Imaging Advantages

Combining Strengths
- Hybrid imaging should provide some kind of added value.
- To be useful a hybrid imaging system should enable the modalities to do things that they could not do alone.
  - To answer clinical questions that could not be answered using the scanners separately.
  - To improve the quantitative accuracy of functional/molecular imaging studies.
  - To enable clinical or preclinical studies to be done in less time.
  - To reduce costs.
PET/CT Scanners

Siemens Biograph LSO, 2/6/16/64 slice CT
GE Discovery ST BGO, 4/8/16 slice CT
Philips Gemini GSO, 6/10/16 slice CT

PET/CT Advantages

- Provides accurately aligned structural and functional information.

PET/CT Advantages

- CT provides low noise attenuation information in a short time for attenuation correction of the PET emission data.

PET/CT Attenuation correction

- A two segment linear scale is used
  - Different scaling for soft tissues and bone
  - Break point at about 0 - 70 HU unit
  - Bone scale depends on CT kV

Breathing Artifacts: Misregistration Of Lesions

58-y-old man diagnosed with colon cancer. A lesion at the dome of the liver appears erroneously in the lower right lung base on the PET AC image. On the non-AC image all the liver lesions are confined to the liver.

Courtesy P. Kinahan, University of Washington
Preclinical PET/CT

PET and CT images showing distribution of 18F-fluoride ion in a mouse.

Commercial SPECT-CT Scanners

PET/CT and SPECT/CT

› Use of CT for attenuation correction introduces some potential sources of artifacts.
› Non-simultaneous acquisition creates a propensity for motion between scans.
› CT can deliver significant radiation doses dependent on chosen scan parameters.

Trimodality PET/SPECT/CT

TRIMODALITY – Preclinical PET / SPECT / CT

Gamma Medica Triumph II Trimodality System

Siemens Inveon
TRIMODALITY SYSTEMS

Mediso Anyscan - Human PET, SPECT and CT.
http://www.mediso.com

Carestream Albira - uPET, uSPECT and uCT.
http://carestream.com

PET/MR

PMTs and magnetic fields do not mix

- Solution 1: transport the light from the scintillation crystal to the PMTs a distance away (outside the B field)
- Solution 2: replace the PMTs with solid state devices (APDs)

Approaches to PET/MRI

“tandem” PET/MRI
- interference easier to avoid
- largely use existing hardware
- least expensive

“integrated” PET/MRI
- simultaneous PET/MRI possible
- higher throughput
- best image registration

PET Insert

Preamplifiers PSAPDs optical fibers scintillator ring

PET-MRI Set Up

Gradient set RF coil PET insert

Simultaneous in vivo PET and MR imaging

Mouse FDG Tumor Imaging

**PET**
- ~200 µCi ¹⁸F-FDG
- Voxel size: 0.35 x 0.35 x 1.5 mm³

**MRI**
- RARE sequence
- Whole body imaging RF coil
- FOV = 4 x 4 cm²
- Matrix size 256 x 256

©2008 by National Academy of Sciences

PET/MR SYSTEM TYPES

INTEGRATED
- Siemens BrainPET
- PET insert - LSO crystal ring, APDs
- 3T MR
- Simultaneous PET/MR

PET/MR vs PET/CT


Frontobasal meningioma - ⁶⁸Ga-DOTA-TOC

©2008 by National Academy of Sciences
### Why PET/MR?

**Potential Strengths**
- Excellent registration of structural and molecular imaging data with better soft tissue contrast than CT
- Anatomic priors for PET reconstruction, partial volume correction and data modeling
- PET can be combined with advanced MRI techniques such as fMRI, DWI, MR spectroscopy, and MR molecular imaging agents.
- No additional radiation dose.
- Potential to obtain motion information from MRI for motion correction of PET data.

**Weaknesses**
- More expensive than PET/CT
- Attenuation information not directly measured as in CT
- Uncertainty regarding throughput, cost effectiveness and ultimate clinical role.

### OTHER HYBRID IMAGING MODALITIES

**A partial list:**
- PET/MR, PET/CT,...
- SPECT/CT, SPECT/MR,...
- MR/PET, MR/Ultrasound, MR-EIT,..
- Optical/PET, Optical/SPECT, Optical/CT, Optical/MR
- Photoacoustic/Thermoacoustic
- Trimodality – Optical/x-ray/radioisotopic, Magneto-photo-acoustic
- Omnitomography

### HYBRID OPTICAL MODALITIES
**Optical / Planar x-ray / Radioisotope**

Use of co-registered x-ray image for source localization.

- Optical (Luminescence/Fluorescence)
- Radioisotopic
- X-ray

Injected tumour cells labelled with near infra-red fluorophores (fluorescent chemical compounds that can re-emit light upon light excitation).

Hybrid FMT-XCT

Hybrid fluorescence molecular tomography (FMT) / X-ray CT (XCT)

- Hybrid FMT-XCT system built around a GE xSight Locus MicroCT. (1) X-ray source. (2) X-ray detector. (3) XY stage for two lasers, 680nm and 750nm. (4) CCD camera. (5) Filter wheel. (6) Rotating gantry.

**Intracranially injected NIR fluorophores.**

[NIR fluorophores](http://www.carestream.com/invivo–imaging–image–gallery.html)

**Injected tumour cells labelled with near infra-red fluorophores.**

**Photoacoustic Imaging**

- Illuminate biological tissue with pulsed laser light (when radio frequency pulses are used, the technology is referred to as thermoacoustic imaging).
- Molecules (endogeneous or imaging agents with specific optical absorption properties) in tissue heat up and emit sound which can be detected with an ultrasound transducer.
- Optical absorption is closely associated with physiological properties, such as hemoglobin concentration and oxygen saturation.
- Advantage: Inherent co-registration of photoacoustic signal to 2D/3D anatomical target in real-time.

**VEVO LAZR Photoacoustic Imaging System**

[Vevo LAZR Photoacoustic Imaging System](http://www.visualsonics.com/photoacoustic-technology)

Hindlimb of a mouse under non-ischemic (a) and ischemic conditions (b).
**FMT-MR**

Tumour protease activity

Co-registration of 3D FMT and MRI images.

FMT-MR imaging of mouse with implanted glioma.

- Mouse injected i.v. with 2 nmol of ProSense680.
- Fluorescence neuroimaging conducted in a VisEn Medical FMT Fluorescence Molecular Tomography system.
- MRI imaging performed immediately after FMT imaging on a 7 T Bruker Pharmascan MR scanner.
- Co-registration of 3D FMT and the MR images.

**PET-FMT-CT**

Correlation of FMT and PET signal

- Biocompatible nanoparticles (containing a 18F isotope and a far red fluorochrome).
- Mouse with bilateral flank tumours.
- PET/CT performed on Siemens Inveon
- FMT performed on VisEn Medical FMT system
- Images co-registered using fiducial markers
- Correlation in amplitude and location.

**THE FUTURE**

Multi-modality Contrast Agents

- Further refinement of existing hybrid imaging technologies.
- Emergence of new hybrid imaging technologies.
- Development of multi-modality contrast agents.

**Multimodality Probes**

Triple-modality MRI-photoacoustic-Raman (MPR) nanoparticle

Thank you