Image Fusion in Nuclear Medicine
PET/CT       J. A. Patton, Ph.D.

Image Fusion in Nuclear Medicine
PET/CT
AAPM 2001
Continuing Education

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Functional Imaging with Radiopharmaceuticals
• Conventional Nuclear Medicine
  – Bone Scans
  – Lung Scans
  – Cardiac Evaluations
  – Tumor and Infection Imaging
• Positron Emission Tomography (PET)
  – Brain Metabolism
  – Cardiac Metabolism and Ischemia
  – Tumor Metabolism

Fluorodeoxyglucose (FDG)
• A very special radiopharmaceutical
• Labeled with F-18
  – Positron Emitter (511 keV photons)
• Glucose analog
  – Excellent metabolic imaging agent

HCFA Approval for $^{18}$FDG
• 1998
  – Solitary pulmonary nodules
  – Staging of non-small cell lung cancer
• 1999
  – Recurrent colorectal cancer
  – Lymphoma
  – Metastatic melanoma
• 2000
  – Non-small cell lung cancer
  – Colorectal cancer
  – Lymphoma
  – Melanoma
  – Head and neck cancer
  – Bladder cancer
  – Esophageal cancer
  – Myocardial viability
  – (Therapy monitoring excluded)
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Annihilation Radiation

PET Scanner

Detectors

Coincidence Circuits

Signal Electronics

Display

PET Scanner

• 18 rings of detectors
• 35 imaging planes
• 15 cm axial field-of-view

Dedicated PET Scanner

PET scans are acquired as a series of transverse slices with a spatial resolution of approximately 5 mm. Each slice is 7-8 mm thick.

Brain Tumor

MRI  

18FDG PET

15 nanosecond timing window

Transverse Slices  

3-D Volume  

Coronal
Whole Body FDG PET
No Attenuation Correction
Images are created by acquiring data from multiple bed positions.

Transmission Scan  Emission Scan w/o AC  Emission Scan with AC

Problems with Dedicated PET Scanners
- Expensive to purchase
- Expensive to service
- Can only perform PET procedures
- Reimbursement has been a problem (but is now improving)

Hybrid Cameras
- Multi-Head Scintillation Camera
- Routine nuclear medicine procedures
- Collimated high energy imaging
- Coincidence imaging (PET)

Dual-Head Scintillation Camera
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**Coincidence Counting with a Dual-Head Scintillation Camera**

- Head A
- Head B
- Coincidence Circuit
- A(x1,y1), B(x1,y1)

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**Metastatic Lung Cancer**

Without Attenuation Correction

- Transverse
- Coronal
- Sagittal

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**Attenuation Correction**

- Generally performed with a transmission scan obtained using a radioactive source as in PET scanning.

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**Dilemma in Nuclear Medicine**

- Referring physicians ask “You have identified an area of increased uptake. Where is the abnormality located?”
- Nuclear medicine images must then be compared with images from CT or MRI.
  - Physiology - domain of nuclear medicine
  - Anatomy - domain of CT and MRI

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**Image Fusion**

- Molecular Function + Anatomical Detail (Nuclear Medicine) (CT or MRI)

- Functional and Anatomical Imaging

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**Overlay Images for Comparison**
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Traditional Methods
• Software Registration/Fusion
  – Rigid Body Transformations
    • Head
  – Non-rigid Body Transformations
    • Body

CT/MRI Scan

Emission Scan

Fused Image

Mathematical Transformation

Traditional Methods

Rigid Body Transformations
PET → MRI

Input Images
Registered Images

Stereotactic Head Frame

GE Millennium with “Hawkeye”

CT Acquisition
10 mm slice
13.6 sec/slice
40 slices

X-Ray Tube
140 kVp max.
2.5 mA max.

Slip ring gantry

Problems
• Images are acquired:
  – With different modalities
  – With different spatial resolutions
  – At different times
  – With patient in different positions
  – With different pixel sizes
  – With different array sizes
• And organs move
  – Cardiac/Respiratory/GI
Transmission Maps for Attenuation Correction and Image Fusion

Transverse | Coronal | Sagittal

Attenuation maps are displayed in Hounsfield Units and measured attenuation coefficients are scaled to 511 keV for attenuation correction.

Functional Anatomical Mapping

Testicular Cancer
Elevated tumor markers
$^{18}$FDG

Metastatic Liver Cancer

SPECT of Chest with $^{99m}$Tc Sestamibi in Patient with Parathyroid Adenoma
Results

- In a limited series of patients, image fusion provided added clinical value in 35% of the studies.

Hybrid Camera/CT

- Advantages
  - Relatively low cost
  - Multiple functions
- Disadvantages
  - Lesion detectibility problems for lesions < 1.5 cm
  - CT images are not diagnostic CT quality
**PET/CT**

- **Advantages**
  - Improved lesion detectibility
  - High quality anatomical information
  - Increased speed → Improved throughput
  - High quality fusion images
- **Disadvantage**
  - Cost

**Image Fusion Applications**

- Radiation therapy treatment planning
  - Conformal Therapy uses multi-leaf collimators to shape the radiation beam
  - Intensity Modulated Radiation Therapy (IMRT) permits the altering of the intensity of the radiation beam
- Use fused images as input for therapy treatment planning
  - to increase accuracy of radiation field mapping for therapy
  - Evaluate response to therapy

**Advantage of Nuclear Medicine**

Nuclear medicine provides information on regional biological activity that anatomical images alone cannot provide. This is useful for treatment planning and monitoring therapeutic response.

**Plan Variation**

- CT Isocenter
- Nuclear Medicine Isocenter

**18FDG Lung Cancer**
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18FDG Lung Cancer
Coronal View

18FDG Lung Cancer
Sagittal View

Tumor at Base of Tongue

Varian See and Treat™ Cancer Care
Data input from GE VG with Hawkeye

Varian Helios IMRT Treatment Plan
Using co-registered VG Coincidence and
Hawkeye CT data sets

Acceptance Testing and Q.A.
- Perform routine CT procedures
- Perform routine PET/Camera procedures
- Verify accuracy of registration
  - Phantom measurements
  - Remember data are three dimensional
  - Watch for flexing of imaging table

Varian SomaVision treatment planning workstation

Varian SomaVision treatment planning workstation
Conclusions

- Image fusion appears to be a valuable tool to:
- Precisely locate and identify lesions
- Refine radiation therapy treatment plans
- Follow course/effects of therapy