Complimentary role of Anatomical & Molecular Imaging

- Anatomical imaging (CT or MRI): best imaging modalities to evaluate the relationship between organs and vascular structures.

- SPECT and PET: provide functional images but lack anatomical landmarks for accurate localization.

- Optimal interpretation and localization is obtained when both are interpreted in conjunction with each other.
Correlation of Anatomical and Functional Images

• Visual correlation

• Fusion of images obtained separately using registration software
  – Straightforward for rigid structures (e.g. brain)
  – Problems with non-rigid structures (e.g. body)
    • Breath-hold versus breathing
    • Internal motion of organs
    • Position of the patient on the imaging table

• Integrated imaging systems
  – SPECT/CT
  – PET/CT
  – PET/MRI
Clinical Applications for Hybrid SPECT/CT

- Clinical Indications:
  - Cardiac attenuation correction
  - Neoplasms
    - Thyroid carcinoma ($^{131}$I-iodide)
    - Parathyroid adenoma ($^{99m}$Tc-MIBI)
    - Somatostatin receptor-positive tumors ($^{111}$In-Octreotide)
    - Pheochromocytoma/Neuroblastoma (I-MIBG)
    - Hemangioma ($^{99m}$Tc-RBC)
    - Focal nodular hyperplasia ($^{99m}$Tc-sulfur colloid)
    - Splenosis
    - Sentinel node localization
    - Skeletal ($^{99m}$Tc-MDP)
    - Prostate carcinoma ($^{111}$In-Prostascint)
  - Infection ($^{111}$In- and $^{99m}$Tc-WBC)
  - Bone trauma ($^{99m}$Tc-MDP)

Thyroid Carcinoma with $^{131}$I-SPECT/CT

- Review of 71 patients
  - Vanderbilt: n = 39, Rambam Medical Center: n = 32
  - Post-therapy: n = 54, Diagnostic scintigraphy: n = 17

- Incremental Diagnostic Value of $^{131}$I-SPECT-CT over planar imaging in 57% of patients:
  - Precise localization
    - In the neck: 21% of patients
    - To the skeleton: 17% of patients
  - Characterization as physiologic or benign: 13%

- Incremental clinical value:
  - Impact on therapy:
    - Surgery versus $^{131}$I-therapy
    - Dose for $^{131}$I-therapy
  - Impact on prognosis

A 60-year-old female s/p total thyroidectomy for papillary thyroid carcinoma was evaluated for metastases.

Diagnosis: Probable metastases in the neck and left femur. A bone radiograph of the left femur was normal.
A 60-year-old female s/p total thyroidectomy for papillary thyroid carcinoma was evaluated for metastases.

Diagnosis: Metastases in the neck and precisely localized in the left femur on the SPECT/CT images.
• A 53 year-old male with papillary thyroid carcinoma
  – Stage II, T2 Nx Mx

• $^{123}$I scintigraphy prior to radioactive iodine therapy therapy
• A 53 year-old male with papillary thyroid carcinoma
Parathyroid Adenoma with $^{99m}$Tc-MIBI-SPECT/CT

- Modification of Surgical Approach
  - 36 patients with primary hyperparathyroidism
  - Impact on management of 39% patients
    - Retrotracheal parathyroid glands
    - Ectopic parathyroid adenoma
    - Distorted neck anatomy

Parathyroid Adenoma with $^{99m}$Tc-MIBI-SPECT/CT

- A 75 year-old male with primary hyperparathyroidism
  - Serum Calcium: 10.4 mg/dL
  - PTH: 142 pg/mL
A 53-year-old male with hyperparathyroidism: the fusion SPECT/CT image allowed precise localization of the focus of uptake in the left mediastinum. Brown tumors are also seen in the ribs.
Neuroendocrine Tumors with SPECT/CT

- 54 patients with known or suspected neuroendocrine tumors
  - $^{111}$In-octreoscan: $n = 43$
  - $^{123}$I-MIBG: $n = 11$
  - High-end spiral CT with contrast: $n = 54$

- Comparison SPECT and high-end CT for 120 lesions
  - Histopathology or follow-up for 114 lesions
  - Concordance: 49% of lesions
  - Discordance: 51% of lesions

Neuroendocrine Tumors with SPECT/CT

• Value of fusion images for discordant lesions:
  – 31 equivocal or benign -> malignant
  – 27 equivocal or malignant -> benign
  – Highest accuracy (99%) by combined analysis SPECT and high-end CT.

• Impact on therapy of image fusion: 28% (14/50) patients
  – Sparing of unnecessary surgery (n = 8)
    • Benign (n = 5), metastases (n = 3)
  – Surgical approach changed (n = 4)
  – Medical treatment changed (n = 2)

A 39 year-old male with suspected pancreatic neuroendocrine tumor.  
$^{111}$In-Octreotide
A 39 year-old male with suspected pancreatic neuroendocrine tumor.

$^{111}$In-Octreotide

24 hour SPECT
A 39 year-old male with suspected pancreatic neuroendocrine tumor.

Pathology: Well-differentiated/intermediate grade pancreatic endocrine neoplasm measuring 2.4 X 2.4 X 2.0 cm.
Sentinel Node Localization with SPECT/CT

- 34 patients with sentinel LN localization (28 melanoma and 6 SCC of head and neck)

- SPECT/CT imaging identified:
  - Multiple draining basins in:
    - 50% (6/12) of patients with trunk melanoma
    - 33% (3/9) of patients with head and neck SCC
  - Sentinel LN missed on planar images in 43% (9/21) of patients, two of which were involved by tumors:
    - Three located close to injection site
    - Two in-transit LN
    - Fourth in an additional basin

A 42 year-old male with a right parietal scalp melanoma referred for sentinel node localization

Planar images show migration inferior to the right ear.

SPECT/CT localize the sentinel node in the posterior triangle in the right occipital chain.

From Delbeke D & Israel O (eds): Hybrid PET/CT and SPECT/CT Imaging – A Teaching File. Springer 2009.
A 52 year-old male with Clark level IV invasive melanoma of the mid-upper back
A 52 year-old male with Clark level IV invasive melanoma of the mid-upper back
A 73 year-old male with prostate cancer - elevated PSA following prostatectomy
A 73 year-old male with prostate cancer - elevated PSA following prostatectomy
Integrated PET/CT Imaging System

Benefit of the combined technique:
1) Attenuation correction with CT
2) Anatomical localization
FDG PET and PET/CT: Impact on Management

• Diagnostic Accuracy

  – **FDG PET**: superior diagnostic accuracy than conventional imaging for staging and restaging FDG-avid malignancies

  – **PET/CT**: incremental impact on diagnostic accuracy: 40-50% patients
    – Discriminating metastatic from physiologic foci
    – Improving lesions detection on both PET and CT
    – Precise localization of metastatic foci
FDG PET and PET/CT: Impact on Management

- **Impact on Management:**
  - **FDG PET:** ~30% patients (range 10%-60%)
  - **PET/CT:** incremental impact on Patient’s management: 10-20% patients, including
    - Planning radiation therapy
    - Guiding biopsies
## FDG PET and PET/CT: Impact on Management

<table>
<thead>
<tr>
<th>Disease Process</th>
<th>Author</th>
<th>Year</th>
<th># patients</th>
<th>Modality</th>
<th>Comparison</th>
<th>Change of management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed tumors</td>
<td>Bar-Shalom 10</td>
<td>2003</td>
<td>204</td>
<td>FDG PET/CT</td>
<td>PET alone</td>
<td>14%</td>
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<tr>
<td>Mixed tumors</td>
<td>Roman 11</td>
<td>2005</td>
<td>173</td>
<td>FDG PET/CT</td>
<td>PET alone</td>
<td>12.5%</td>
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<tr>
<td>Mixed tumors</td>
<td>Hillner 12 (NOPR)</td>
<td>2008</td>
<td>22,975</td>
<td>FDG PET (16%) PET/CT (84%)</td>
<td>Referring physician questionnaire</td>
<td>36.5%</td>
</tr>
</tbody>
</table>

**NOPR: National Oncologic PET Registry**

A Nationwide (US) Collaborative Program

- Nationwide prospective registry

- **Goal:**
  - Evaluate the impact of PET on physician plans of patient management

- **Providers:**
  - Pre-PET and post-PET physician questionnaires
    - condition for reimbursement
NOPR: Results

Overall Impact on Patient Management
- Diagnosis, Staging, Restaging, Recurrence
- Data on 22,975 scans from May 8, 2006 – May 7, 2007

Impact on Patient Management by Cancer Type
- Staging, Restaging, Recurrence (proven cancer type)
- Data on 40,863 scans from May 8, 2006 – May 7, 2008

Treatment Monitoring
## NOPR: National Oncologic PET Registry

<table>
<thead>
<tr>
<th>Pre-Pet Plan</th>
<th>Post-PET Plan</th>
<th>Clinical Indication for PET Study (%)</th>
<th>All n=22,975</th>
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</thead>
<tbody>
<tr>
<td>Treat</td>
<td>Same</td>
<td>Dx n=5,616</td>
<td>16.0</td>
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<tr>
<td></td>
<td></td>
<td>Staging n=6,464</td>
<td>46.5</td>
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<tr>
<td></td>
<td></td>
<td>Restaging n=5,607</td>
<td>15.8</td>
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<tr>
<td></td>
<td></td>
<td>Recurrence n=5,388</td>
<td>20.4</td>
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<tr>
<td>Non-Treat</td>
<td>Same</td>
<td>Dx n=5,616</td>
<td>52.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Staging n=6,464</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restaging n=5,607</td>
<td>48.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recurrence n=5,388</td>
<td>40.7</td>
</tr>
<tr>
<td>Non-Treat</td>
<td>Treat</td>
<td>Dx n=5,616</td>
<td>23.2</td>
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<tr>
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<td>Staging n=6,464</td>
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<tr>
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<td>29.2</td>
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<td>Treat</td>
<td>Non-Treat</td>
<td>Dx n=5,616</td>
<td>7.9</td>
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<td></td>
<td>Recurrence n=5,388</td>
<td>9.7</td>
</tr>
<tr>
<td>Patients with change post-PET (%)</td>
<td>Dx n=5,616</td>
<td>Staging n=6,464</td>
<td>Restaging n=5,607</td>
</tr>
</tbody>
</table>

**PET Changed Intended Management in 36.5% of Cases**

Lung Cancer
PET/CT for Radiation Treatment Planning

- Change TNM stage: 25-30%
- Change treatment from curative to palliative: 10-25%
- Increase GTV: LN not meeting size criteria
- Decrease GTV: atelectasis, post-obstructive pneumonia

Lung Cancer (NSCLC): Initial Staging
The PLUS Multicenter Randomized Trial

• 188 patients from 9 hospitals were randomized to
  – Conventional work-up (CWU)
  – CWU + PET

• End point: futile (unnecessary) thoracotomy

• Results
  – CWU: 41% futile thoracotomy
  – CWU + PET: 21% futile thoracotomy
  ➔ Decrease in unnecessary surgery by 50%

63-year-old male with newly diagnosed lung ca

From Delbeke D. Diagnostic Imaging 2003
FDG PET/CT for Breast Cancer

- **Initial staging**
  - *Early breast cancer*: *Sentinel node biopsy is standard of care*
  - **Locally advanced breast:**
    - Increased risk for distant metastases
    - Inner quadrant lesions (internal mammary LN ~ 25%*)
    - Technically difficult or Positive SLNB
    - Equivocal lesions by other modalities

- **Restaging/Therapeutic Response**
  - To replace multiple modalities

- Monitoring chemotherapy of locally advanced disease
  - Identify non-responders early.

PET/CT staging of locally adv. breast CA

• Fuster et al., JCO 2008
  – Prospective, single-center study
  – 60 patients with large primary tumor
  – PET/CT vs conventional (CT, bone scan, liver US)

• Underestimated axillary LN involvement
  – 70% sensitivity, 100% specificity
  – But detected only 29% (24 / 84) involved LNs

• Better detection of distant metastases
  – 100% sensitivity, 98% specificity vs 60% and 83%

• Altered management in 42% (25/60) of patients
  – 18 upstaged (5 distant mets, 13 additional LN disease)
  – 7 downstaged (no distant mets)
## PET/CT Imaging: Impact on Management Breast Cancer

<table>
<thead>
<tr>
<th>Disease Process</th>
<th>Author</th>
<th>Year</th>
<th># patients</th>
<th>Modality</th>
<th>Comparison</th>
<th>Change of management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast cancer</td>
<td>Radan</td>
<td>2006</td>
<td>Suspected Recurrence</td>
<td>FDG PET/CT</td>
<td>Contrasted CT</td>
<td>51%</td>
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<tr>
<td>Breast cancer</td>
<td>Heron</td>
<td>2006</td>
<td>simulation</td>
<td>FDG PET/CT</td>
<td>Radiation therapy planning (simulation)</td>
<td>50%</td>
</tr>
</tbody>
</table>

Summary

• Hybrid PET/CT and SPECT/CT
  – Incremental diagnostic value over:
    • PET or SPECT alone
    • PET or SPECT correlated with separate CT
Summary

• Hybrid PET/CT and SPECT/CT
  – Improved lesion detection
  – Precise lesion localization
  – Differentiation of physiologic from pathologic uptake
Summary

• Hybrid PET/CT and SPECT/CT
  – Affect clinical management by:
    • Guiding further procedures
    • Excluding the need for further procedures
    • Changing inter- and intramodality therapy
    • Providing prognostic information