The Role of PET / CT in Lung Cancer Staging

Vlad Vinarsky, Harvard Medical School Year IV
Gillian Lieberman, MD
Patient AM

HPI:

- 81 yo F p/w hemoptysis x 1 month
- LLL lesion on CXR, not responsive to Abx
- 35 pack-year smoking history, quit 12 years ago
- Chest CT at OSH revealed a “spiculated 3 cm mass in LLL” (images not available)

Work-Up at BIDMC:

- Bronchoscopy and tranbronchial biopsy of LLL: “Consistent with poorly differentiated, non-small cell carcinoma.”
- PET / CT for lung cancer staging:
Anatomy of an PET / CT Report

1. PET/CT Modality
2. Use of PET/CT in NSCLC Staging

http://home.caregroup.org/
“The Chemistry”

1. Produce a positron-emitting isotope (F-18)
2. Conjugate to Glucose (FDG)
3. IV-FDG
4. PET scan in 1 hour

http://www.nuk.med.tu-muenchen.de/forschung/information/radiopharma.shtml
The patient’s fasting blood glucose level, measured by glucometer before injection of FDG, was 86 mg/dL.

Physiologic uptake is seen in the myocardium, liver, spleen, kidneys, and bladder.

Neurovascular structures is symmetrical bilaterally, and this focal, abnormal uptake is suspicious for metastatic disease.

Physiologic uptake is seen in the myocardium, liver, spleen, kidneys, and bladder.

Impression: 1) Abnormal FDC uptake in patients known lung tumors, with abnormal FDG uptake in bilateral nodes, and AP window node, and peritoneal node, and in a small, tiny pre-tracheal lymph node at the origin of the aorta vessels.
2) Focal areas of abnormal FDG uptake in the left lung. While it is conceivable that this could represent degenerative change, the very asymmetrical appearance

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The Biology and Physiology of PET
“Metabolic / Functional Imaging”

Cancer Cells: high Glc uptake
- higher overall metabolism
- less FFA metabolism
- hypoxic tissue, less reliance on TCA-cycle

Physiologic Uptake of FGD in:
- brain; myocardium
- muscle; liver
- kidney, bladder
- bone marrow

adapted from http://research.bidmc.harvard.edu/VPtutorials/pulmNodule/tutorialShow
The Physics of PET / CT
(made ridiculously simple)

“The Physics”

1. F-18 emits positrons as it decays

2. Positrons annihilated by electrons in the tissues

3. Two 511 keV photons are emitted in at 180°

4. Photons detected by BGA
The **CT** in PET / CT: Attenuation Correction

**The Advantages of CT:**

1. Faster image acquisition (attenuation correction by CT)

2. Improved lesion localization (no published proof)
   - chest wall vs lung
   - base of lung vs liver
   - neck vs superior mediastinum
   - distal esoph (often normal) vs paraesoph node (N2)
PET / CT
SCANNER

adapted from http://bidmc.harvard.edu/display.asp?node_id=3547
Sample PET / CT

CT

PET, attenuation-corrected

FUSION Image

PET; non-corrected

Courtesy of Dr. Parker
DDX of an FDG-Avid Area in BONE

FALSE POSITIVES

1. Physiologic Uptake

2. Pathology
   - malignancy
   - granulomatous disease (fungal infections: coccidiomycosis, histoplasmosis, aspergillosis, TB)
   - infection
   - sarcoidosis
   - inflammation (DJD)

FALSE NEGATIVES

- some tumors are less FDG-avid (carcinoid, bronchioalveolar)
- nodule too small (esp. micromets in LNs)
- brain: very high background
- hyperglycemia
- too much attenuation correction

Sensitivity: 95% for >8mm lesion
Indications for PET / CT

- **Diagnosis**: especially SPN

- **Staging**: prognosis and avoidance of ineffective surgery and radiation therapy

- **Localization**: ability to guide surgical mediastinal bx and XRT

- **Restaging**: monitor response to therapy and surveillance after curative tx

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Radiology Order Entry (Nuclear Med) Pet Oncology

Exam:

- PET, BREAST CA, DIAGNOSIS
- PET, BREAST CA, RECURRENCE
- PET, BREAST CA, RESPONSE TO TREATMENT
- PET, COLORECTAL, DIAGNOSIS
- PET, COLORECTAL, INITIAL STAGING
- PET, COLORECTAL, RESTAGING
- PET, ESOPHAGEAL CA, DIAGNOSIS
- PET, ESOPHAGEAL CA, INITIAL STAGING
- PET, ESOPHAGEAL CA, RESTAGING
- PET, HEAD AND NECK CA, DIAGNOSIS
- PET, HEAD AND NECK CA, INITIAL STAGING
- PET, LUNG CA, DIAGNOSIS
- PET, LUNG CA, INITIAL STAGING
- PET, LUNG CA, RESTAGING
- PET, LYMPHOMA, DIAGNOSIS
- PET, LYMPHOMA, INITIAL STAGING
- PET, LYMPHOMA, RESTAGING
- PET, MELANOMA, DIAGNOSIS
- PET, MELANOMA, INITIAL STAGING
- PET, MELANOMA, RESTAGING
- PET, OTHER TUMORS
- PET, THYROID, RESTAGING

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PET/CT Report for Patient AM:

Indication: Lung cancer, staging.

The patient was a 65-year-old male with a history of smoking. The examination was performed to evaluate the presence of lung cancer and to stage the disease.

**FINDINGS:**

1. **Abnormal FDG uptake in the left lung:** The PET/CT scan revealed abnormal FDG uptake in the left lower lobe of the lung. The SUV was 6.5, indicating an active lesion.

2. **Abnormal FDG uptake in the liver:** There was increased FDG uptake in the liver, with an SUV of 4.2. This could be indicative of metastatic disease.

3. **Abnormal FDG uptake in the cervical lymph nodes:** Multiple lymph nodes in the cervical region showed increased FDG uptake, with an SUV of 5.8.

4. **Abnormal FDG uptake in the mediastinal lymph nodes:** There was significant FDG uptake in the mediastinal lymph nodes, with an SUV of 4.5.

**Conclusion:**

The PET/CT scan was consistent with the clinical presentation of lung cancer. The spread to the liver and lymph nodes suggests advanced disease. Further investigations are recommended to confirm the diagnosis and plan appropriate treatment.

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Staging Algorithm for Non-Small Cell Lung Cancer

Contrast-enhanced CT of the chest including liver and adrenals

All others

Suspected distant metastases

Biopsy to confirm

PET SCAN

Negative mediastinal uptake, negative distant mets

Mediastinoscopy, thoracotomy, or transbronchial needle biopsy to sample suspicious lymph nodes

CT-positive mediastinum

Mediastinoscopy, thoracotomy, or transbronchial needle biopsy to sample suspicious lymph nodes

CT-negative mediastinum

Surgical staging or thoracotomy

Suspected T4 N3 or M1 disease (mediastinal invasion, pleural disease)

Biopsy to confirm Transbronchial needle biopsy, thoracentesis, mediastinoscopy, CT-guided FNA or surgery to determine if T4

† The role of positron emission tomography (PET) for locoregional staging of non-small cell lung cancer is evolving. Some centers recommend surgical staging of the mediastinum even in the setting of a negative CT and PET scan of the mediastinum, while others proceed directly to attempted resection.
PET/CT Report:
Finding 1 in Patient AM

FINDINGS: There is avid FDG uptake within the patient's left lower lobe lung mass (SUV 9.3).

IMPRESSION: 1) Abnormal FDG uptake in patient's left lower lung, with abnormal FDG uptake in hilar lymph nodes, and an abnormal node in the left hilum. 2) Abnormal FDG uptake in the left hilum. 3) The appearance is suspicious for early osseous metastatic disease.

Vlad Vinarsky, HMS IV
Gillian Lieberman, MD

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Finding 1 in Pt AM: Left Lower Lung Mass (T1)

“T1 lesion is less than 3cm in diameter and is considered to be easily resectable, being located in the periphery of the lung.”

**SUV: Standardized Uptake Value**

\[
\text{SUV} = \frac{\text{tracer activity in ROI}}{\text{dose of tracer injected}}
\]

(cut-off SUV>2.5)
PET/CT Report: Finding 2 in Patient AM

Abnormal FDG uptake is also noted in two left hiliar lymph nodes (SUV of the larger node 8.9), and within a AP window lymph node (SUV 6.2). There is a faint area of FDG uptake noted in the pre-tracheal region near the origin of the great vessels, which emanate from a single trunk from the aorta. A very tiny soft tissue attenuation structure is seen in this area, and this likely represents abnormal nodal FDG uptake as well (SUV 2.8). Additionally, there is abnormal FDG uptake within a paraesophageal node at the level of the dome of the liver (SUV 4.1).

http://home.caregroup.org/
Finding 2 in Pt AM: FDG-Avid Hilar Node
Finding 2 in Pt AM: Paraesophageal Node
FDG-Avid Hilar and Paraesophageal Nodes (N2)

Regional Lymph Node Stations for Lung Cancer Staging

Superior mediastinal nodes
1. Highest mediastinal
2. Upper paratracheal
3. Prevascular and retrotracheal
4. Lower paratracheal (including azygos nodes)

Aortic nodes
5. Subaortic (A-P window)
6. Paraaortic (ascending aorta or phrenic)

Inferior mediastinal nodes
7. Subcarinal
8. Paraesophageal (below carina)
9. Pulmonary ligament

N1 nodes
10. Hilar
11. Interlobar
12. Lobar
13. Segmental
14. Subsegmental

N2 any ipsilateral single digit node
N3 any contralateral or any supraclavicular node

Ao; aorta, PA; pulmonary artery. Adapted from Mountain, CF, Dresler, CM. Chest 1997; 111:1718.
NSCLC Staging: TNM System

NSCLC 1997 Revised Staging Matrix -
Click on a stage of disease to see the anatomic structures involved.

Designed by Justin P. Lafreniere 2002
Lung diagram courtesy of UTHSCSA

http://research.bidmc.harvard.edu/VPtutorials/pulmNodule/images/Staging%20movie_final.html
Patient appears to be Stage IIIa except...
PET/CT Report: Finding 3 in Patient AM

There is also an area of abnormal FDG uptake within the left iliac bone (SUV 3.4). This is located immediately adjacent to the sacroiliac joint. There is subtle sclerosis of this area on the CT images. The appearance of the sacroiliac joint osseous structures is symmetrical bilaterally, and this focal abnormal uptake is suspicious for metastatic disease.

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Finding 3 in Pt AM: Metastatic Disease in the Ileum

DDX for FDG-Avid Lesion in Bone
- malignancy
- Bone Marrow (normal)
- inflammation (DJD)
- tendonitis / tendon insertion
Patient AM

• PET/CT suggested metastatic disease (Stage IV) --> conservative chemotherapy was initiated

• Technical difficulties with biopsy and MRI of ilium

• Repeat PET/CT, when aggressive chemo-radiation and surgery were still being considered, showed dramatic progression of cancer with clear bony mets
Patients AM

PET/CT changed patient management by preventing unnecessary chemoradiation and surgery
Follow-Up PET/CT

Courtesy of Dr. Parker
PET / CT Affects Management of NSCLC Patients

Table 2. Diagnostic Accuracy of the Imaging Methods with Respect to Tumor Stage in 40 Patients.

<table>
<thead>
<tr>
<th>Imaging Method</th>
<th>Classification Correct (Score of 3)</th>
<th>Classification Correct but Equivocal (Score of 2)</th>
<th>Classification Incorrect (Score of 0 or 1)</th>
<th>no. of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT alone</td>
<td>23 (58)</td>
<td>8 (20)</td>
<td>9 (22)</td>
<td></td>
</tr>
<tr>
<td>PET alone</td>
<td>16 (40)</td>
<td>16 (40)</td>
<td>8 (20)</td>
<td></td>
</tr>
<tr>
<td>Visual correlation of PET and CT</td>
<td>26 (65)</td>
<td>5 (12)</td>
<td>9 (22)</td>
<td></td>
</tr>
<tr>
<td>Integrated PET–CT</td>
<td>35 (88)</td>
<td>4 (10)</td>
<td>1 (2)</td>
<td></td>
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</tbody>
</table>

Table 3. Diagnostic Accuracy of the Imaging Methods with Respect to Node Stage in 37 Patients.

<table>
<thead>
<tr>
<th>Imaging Method</th>
<th>Classification Correct (Score of 3)</th>
<th>Classification Correct but Equivocal (Score of 2)</th>
<th>Classification Incorrect (Score of 0 or 1)</th>
<th>no. of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT alone</td>
<td>22 (59)</td>
<td>2 (5)</td>
<td>13 (35)</td>
<td></td>
</tr>
<tr>
<td>PET alone</td>
<td>18 (49)</td>
<td>14 (38)</td>
<td>5 (14)</td>
<td></td>
</tr>
<tr>
<td>Visual correlation of PET and CT</td>
<td>22 (59)</td>
<td>4 (11)</td>
<td>11 (30)</td>
<td></td>
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<tr>
<td>Integrated PET–CT</td>
<td>30 (81)</td>
<td>1 (3)</td>
<td>6 (16)</td>
<td></td>
</tr>
</tbody>
</table>

- Bar-Shalom et. al. (2003) study shows impact on treatment of 14% patients
- Antoch G. et. al. (2003) shows impact on staging in 30% patients and impact on treatment in 19% of patients
Summary

PET/CT Affects Staging and Patient Management in NSCLC

Future

• PET / High-Resolution CT
• Tumor-specific Radiopharmaceuticals
Thank You

• J. Anthony Parker, MD
• Jeff English, PET/CT Tech
• Steve Eiger, PhD
• Gillian Lieberman, MD
• Pamela Lepkowski
• Larry Barbaras our Webmaster
References

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