Thoracic Imaging: Update 2010

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Director of Thoracic Imaging and Intervention, MGH
Professor of Radiology, Harvard University
Lobar Atelectasis
“S” Sign of Golden
Laurence L. Robbins, MD
The Roentgen Appearance of Lobar and Segmental Collapse of the Lung: A Preliminary Report

LAURENCE L. ROBBINS, M.D., and CLAYTON H. HALE, M.D.

Boston, Mass.
Aubrey O. Hampton, MD
Hampton’s Hump
Objectives

- Diagnosis of thromboembolic disease
- Lung cancer
  - Diagnosis
  - Staging
  - Treatment
- Future directions
Multidetector Computed Tomography for Acute Pulmonary Embolism

Paul D. Stein, M.D., Sarah E. Fowler, Ph.D., Lawrence R. Goodman, M.D., Alexander Gottschalk, M.D., Charles A. Hales, M.D., Russell D. Hull, M.B., B.S., M.Sc., Kenneth V. Leeper, Jr., M.D., John Popovich, Jr., M.D., Deborah A. Quinn, M.D., Thomas A. Sos, M.D., H. Dirk Sostman, M.D., Victor F. Tapson, M.D., Thomas W. Wakefield, M.D., John G. Weg, M.D., and Pamela K. Woodard, M.D., for the PIOPED II Investigators®
**Table 5. Positive and Negative Predictive Values of CTA, as Compared with Previous Clinical Assessment.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>High Clinical Probability</th>
<th>Intermediate Clinical Probability</th>
<th>Low Clinical Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No./Total No.</td>
<td>Value (95% CI)</td>
<td>No./Total No.</td>
</tr>
<tr>
<td>Positive predictive value of CTA</td>
<td>22/23</td>
<td>96 (78–99)</td>
<td>93/101</td>
</tr>
<tr>
<td>Positive predictive value of CTA or CTV</td>
<td>27/28</td>
<td>96 (81–99)</td>
<td>100/111</td>
</tr>
<tr>
<td>Negative predictive value of CTA</td>
<td>9/15</td>
<td>60 (32–83)</td>
<td>121/136</td>
</tr>
<tr>
<td>Negative predictive value of both CTA and CTV</td>
<td>9/11</td>
<td>82 (48–97)</td>
<td>114/124</td>
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</tbody>
</table>

* The clinical probability of pulmonary embolism was based on the Wells score: less than 2.0, low probability; 2.0 to 6.0, moderate probability; and more than 6.0, high probability. CI denotes confidence interval.
† To avoid bias for the calculation of the negative predictive value in patients deemed to have a low probability of pulmonary embolism on previous clinical assessment, only patients with a reference test diagnosis by ventilation–perfusion scanning or conventional pulmonary DSA were included.
PE Diagnostic Trends

Pulmonary angiograms
V/Q scans

PECT
Dual-Energy Computed Tomographic Pulmonary Angiography: A Pilot Study to Assess the Effect on Image Quality and Diagnostic Confidence

Minal J. Sangwaiya, MBBS, MRCS, MD, Mannudeep K. Kalra, MD, Amita Sharma, MD, Elkan F. Halpern, PhD, Jo-Anne O. Shepard, MD, and Subba R. Digumarthy, MD
FIGURE 1. Motion artifacts in DE-CTPA performed in an 81-year-old man. A, Respiratory motion in a transverse CT image (lung window). B, Motion artifact compounding vessel contrast in pulmonary arteries in a 140-kVp image. C, Excellent vessel contrast in the 80-kVp image despite motion artifacts. D, Optimal vessel contrast and less image noise in a dual-energy image. All the mediastinal window images (B-D) are displayed at the same window level (50) and width (400).
FIGURE 2. Transverse images of an 81-year-old man who underwent a DE-CTPA showing the difference in contrast opacification of the right lower lobar pulmonary artery by the 140-kVp (A), 80-kVp (B), and dual-energy images (C). There is higher-contrast opacification in the 80-kVp (HU +/- objective image noise, 557.9 HU +/- 37.3) and dual-energy images (378.3 HU +/- 20.2) compared with the 140-kVp image (HU 277.9 +/- 37.4).
FIGURE 3. Transverse 80-kVp (A), 140-kVp (B), and dual-kilovolt (peak) images (C) from a DE-CTPA study performed in an 85-year-old man showing pulmonary embolism (white arrows) in the right lower lobar pulmonary arteries. The filling defect in the right lower lobar pulmonary artery is equally well seen on all 3 images.
Advances in Lung Cancer

- Diagnosis
- Staging
- Treatment
PET/CT: Major Indications NSCLC

- Evaluation of the SPN
- Lung cancer staging
- Evaluation of response to therapy
- Detection of tumor recurrence
NSCLC: FDG PET Staging

- Very high NPV (PET 93%, CT 85% Wahl et al)
- Improves the staging of patients by identifying mediastinal and extrathoracic disease
- Decreased unnecessary thoracotomies
- Correlation/registration with CT findings is essential for accurate assessment
# Sensitivity of FDG-PET vs FDG-PET/CT

<table>
<thead>
<tr>
<th>Study</th>
<th>TNM</th>
<th>FDG-PET</th>
<th>FDG-PET/CT</th>
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</thead>
<tbody>
<tr>
<td>Halpern</td>
<td>T</td>
<td>67%</td>
<td>97%</td>
</tr>
<tr>
<td>Lardinois</td>
<td>N</td>
<td>49%</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>40%</td>
<td>88%</td>
</tr>
<tr>
<td>Aquino</td>
<td>N</td>
<td>59-76%</td>
<td>71-76%</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>53-62%</td>
<td>73-76%</td>
</tr>
<tr>
<td>Antoch</td>
<td>Overall</td>
<td>74%</td>
<td>96%</td>
</tr>
</tbody>
</table>

*McLoud et al  Sensitivity of CT for staging mediastinal disease (1cm threshold) 64%
NSCLC with T2 nodal disease
NSCLC with T3 nodal disease
NSCLC with Left Adrenal Metastasis
PET/CT: Tumor Recurrence
FDG PET Evaluation of SPN

Ability to identify tumors depends on:

- Underlying hyperglycemia
- Size of tumor
- Metabolic activity of a tumor
- Presence or absence of inflammation
FDG PET Evaluation of SPN

- Tumors with low metabolic activity
  - Well-differentiated adenocarcinoma
  - Bronchioloalveolar carcinoma (BAC)
  - Carcinoid tumors

FDG-PET negative non-small cell lung cancer
False Positive Nodules

- Organizing Pneumonia
- Atypical Mycobacterial infection
- Rounded Atelectasis
- Talc Pleurodesis
- Sarcoidosis
PNB: Indications

- PNB is safe and accurate
- Cytologic/histologic evaluation of focal benign and malignant lesions
- Evaluation of suspected focal infections
- Lung, mediastinal, hilar, pleural and chest wall lesions
- Molecular profiling
PNB: Chronology

- 1970  Co-axial needle biopsy, fluoroscopy
- 1982  CT-guided biopsy
- 1985  On-site cytopathology
- 1988  Dependent precautions
- 1992  Radiology recovery room
- 1995  Core biopsy
- 2002  Conscious sedation/nursing
- 2003- Molecular profiling
- 2003- Radiofrequency ablation
Handling of Specimens
On-site Cytopathology

- Aspirates
- Washings/cell block
- Cores
- Special stains
- Flow cytometry
- Cultures
- Molecular Profiling
Lung Cancer Molecular Profiling: A New Paradigm in Cancer Treatment

Molecular profiles are beginning to drive cancer therapy decisions.

Cancer Patient

Clinical Information

Targeted Therapy

Surgical Resection

Routine Pathology

Molecular Pathology

Courtesy of John Iafrate, MD
BCR-ABL Imatinib
100% CML

HER2 Trastuzumab
20-30% IDC

EGFR Erlotinib/ Gefitinib
20% Lung adenocarcinomas

BRAF V600E PLX4032
50-60% Melanoma

ALK Crizotinib
3-5% Lung adenocarcinoma

Courtesy of John Iafrate, MD
BCR-ABL Imatinib
100% CML

HER2 Tastuzumab
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O’Brien et al., Imatinib Compared with Interferon and Low-Dose Cytarabine for Newly Diagnosed Chronic-Phase Chronic Myeloid Leukemia, NEJM 2003

Romond EH et al., Trastuzumab plus Adjuvant Chemotherapy for Operable HER2-Positive Breast Cancer. NEJM 2005.

Mok et al., NEJM 2009

1799 T>A V600E

Courtesy of John Iafrate, MD
Recurrent Mutations in NSCLC

- Unknown: 47%
- MET amplification: 1%
- BRAF mutation: 3%
- ALK translocation: 4%
- EGFR mutation: 15%
- KRAS mutation: 30%

Courtesy of John Iafrate, MD
Genomic

TL-09-267  20 ng/panel DNA

TL-09-285  3.04ng/panel DNA

Courtesy of John Iafrate, MD
Genomic

TL-09-267  20 ng/panel

TL-09-285  3.04ng/panel DNA

Courtesy of John Iafrate, MD
52 yo Male Never Smoker with Stage IV NSCLC Positive for EML4-ALK

The ALK tyrosine kinase inhibitor crizotinib (PF-02341066) shows remarkable activity in patients with advanced ALK-positive NSCLC

Courtesy of Alice Shaw, MD
48 yo Female Never Smoker with Stage IV NSCLC Positive for EML4-ALK

Pre-Treatment

After 2 cycles Crizotinib
Electromagnetic Navigational Bronchoscopy

CT Scan → DICOM CD

Procedure → Navigation → Biopsy

Planning → Planning file
Electromagnetic Navigational Bronchoscopy

Right Upper Lobe Nodule
20 x 15 x 17mm
RIGHT UPPER LOBE NODULE

Right Upper Lobe Nodule
20 x 15 x 17mm

Adenocarcinoma
Thermal Ablation Techniques

- Surgical resection is gold standard for early stage NSCLC (T1-2 N0 M0) but may not be possible in high-risk pts
- Image-guided ablation techniques
  - RFA
  - Microwave
  - Cryoablation
- RFA most widely employed and studied
RF Ablation of Lung Tumors

- Introduced in 2000
- Promising technique in selected pts
- Suited to image guidance
- Well tolerated
- Normal lung is well suited to RF providing an insulating effect concentrating RF energy in the tumor
RF Ablation

- RF generator supplies RF power to tissue through an electrode
- Alternating RF and electric field causes oscillation of ions in tissue
- Motion of ions causes frictional heating
- Cellular death induced by thermal coagulation necrosis
- Optimal heating to 60-100°C
Multidisciplinary evaluation: Thoracic Oncology, Surgery and Radiotherapy

- Surgery: Lobectomy, Segmentectomy, Wedge resection
- Radiation: Conventional, Stereotactic Body Radiation Therapy (SBRT)
- Radiology: Ablation
Indications

Medically unresectable NSCLC
- Pulmonary/cardiac co-morbidities
- New lesion with hx prior surgery or radiation with impaired function
- Recurrence following radiation or limited resection

Refused conventional therapy
Diagnosis and Staging

- Percutaneous needle biopsy (PNB)
  - Confirm histology
  - Treatment planning
  - Determine sedation

- Staging
  - FDG-PET/CT
  - Mediastinoscopy
  - PNB extrathoracic lesions
Immediate Indicators of Successful Therapy

- Tissue core temperature of at least 60 degrees C (60-100C)
- Groundglass opacity around lesion
- MPRs or 3D imaging for confirmation
Imaging Follow Up
Complications, Treatment Response, Recurrence, Mets

Contrast CT Chest
- Morphologic appearance
- Enhancement characteristics

PET
- Metabolic Activity

<table>
<thead>
<tr>
<th>1</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>36</th>
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<tbody>
<tr>
<td>CT CHEST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PET</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Expected CT Findings

Before RF ablation

1 month later

3 months later

6 months later

9 months later

1 year later

CT Imaging Findings of Pulmonary Neoplasms after Treatment with RFA: Results in 32 Tumors. Bojorski JD et al AJR 2005; 1185:466-471
Features of Local Tumor Progression

- Increase in size beyond 3 months
- Focal bulge
- Focal enhancement
- Eccentric activity on FDG-PET

1 month post RFA

3 month post RFA
Expected PET Findings: 64 yo with BAC

- Peripheral ring with evolution to nodule

Pre RFA

1 month Post RFA

6 months Post RFA
PET/CT Imaging

- PET/CT: Metabolic activity in tumor and surrounding lung

Recurrent NSCLC Post RFA

- Eccentric activity in peripheral ring seen at 1 month
- Recurrence seen at 6 months
Factors Predisposing to Tumor Progression

- Technical factors
- Adjacent vessels >3mm, “heat sink”
- Inadequate ablative margin
- Tumor location
- Tumor size
Local Tumor Progression by Size

Table 3. Summary of local tumor progression by size.

<table>
<thead>
<tr>
<th>Tumor size (cm)</th>
<th>0 - 1.9</th>
<th>2.0 - 3.0</th>
<th>&gt; 3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lesions</td>
<td>23</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>% Local recurrence</td>
<td>21.7</td>
<td>44.4</td>
<td>50.0</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>PRE-ABLATION</th>
<th>POST-ABLATION 3-6 MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Mean FEV1 (L)</td>
<td>1.58 ± 0.71</td>
<td>1.59 ± 0.66</td>
</tr>
<tr>
<td>**Mean % predicted FEV1</td>
<td>62.2 ± 25</td>
<td>61.4 ± 25</td>
</tr>
<tr>
<td>Mean % predicted DL&lt;sub&gt;CO&lt;/sub&gt;</td>
<td>56 ± 25</td>
<td>55.8 ± 22</td>
</tr>
</tbody>
</table>

* t-Test p = 0.39, ** t-Test p = 0.26
Overall 2 yr (78%) and 3 yr (47%) Survival

Figure 1.
### Safety Profile (Chan, JTI 2010)

**TABLE 4. Summary of Complications From 2245 Percutaneous Pulmonary Ablations**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Total (%), Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>443 (28.3, 0-90)</td>
</tr>
<tr>
<td>Chest drain</td>
<td>220 (14.4, 0-63)</td>
</tr>
<tr>
<td>Pleural effusions</td>
<td>231 (14.8, 0-86.7)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>23 (1.5, 0-22.2)</td>
</tr>
<tr>
<td>Abscesses</td>
<td>7 (0.4, 0-6.5)</td>
</tr>
<tr>
<td>Pain</td>
<td>220 (14.1, 0-100)</td>
</tr>
<tr>
<td>Hemoptylisis</td>
<td>67 (4.3, 0-37.5)</td>
</tr>
<tr>
<td>Pyrexia</td>
<td>69 (4.4, 0-65.2)</td>
</tr>
<tr>
<td>Bronchopleural fistula</td>
<td>7 (0.4, 0-33)</td>
</tr>
<tr>
<td>Subcutaneous emphysema</td>
<td>3 (0.2, 0-2.2)</td>
</tr>
<tr>
<td><strong>Procedure-related death</strong></td>
<td>7 (0.2, 0-2.2)</td>
</tr>
</tbody>
</table>
RFA Advantages/Disadvantages

ADVANTAGES
- Single treatment
- Well tolerated
- Conscious Sedation
- Low morbidity and mortality
- Does not affect lung function
- Can be repeated if required

DISADVANTAGES
- Local recurrence 20-40%
- Size >3 cm
- Adjacent vessel: Heat sink
- Adjacent pleural surface
- Adjacent heat sensitive structures
Future Initiatives

- **CT Imaging**
  - NLCST ?Screening
  - CAD
  - Functional Imaging
  - Perfusion Imaging

- **Chest Radiography**
  - Portable DR
  - Wireless Transmission
  - CAD
Future Initiatives

- CT Imaging
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Anand Singh, M.D, Subba Digumurthy, M.D, Hiroyuki Yoshida, PhD, Gordon Harris, PhD
Future Initiatives

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Thank you!