Role of Imaging in Lung Cancer Staging: Update and Controversial Topics

Brett W. Carter, MD

EDUCATIONAL OBJECTIVES

Outline the TNM staging system used for lung cancer
Understand the role of thoracic imaging in the clinical staging of lung cancer
Review specific TNM descriptors through representative examples on imaging studies
Synthesize TNM descriptors into stages and understand the impact on patient management

STAGING SYSTEM

- The 7th edition of the TNM Staging System for lung cancer was published in 2009 & included key revisions
  - Based on findings from the International Staging Project of the International Association for the Study of Lung Cancer

- Database:
  - 100,869 patients
  - 46 institutions/databases
  - 19 different countries

STAGING SYSTEM

KEY REVISIONS

- Changes to T and M descriptors
- No changes to N descriptors
- Inclusion of small cell lung cancer and bronchopulmonary carcinoid

TUMOR (T) SIZE

- T1a ≤2 cm
- T1b >2 cm ≤3 cm
- T2a >3 cm ≤5 cm
- T2b >5 cm ≤7 cm
- T3 >7 cm

SATELLITE NODULES

- T3 Same lobe
- T4 Same lung, different lobe
- M1a Contralateral Lung
**KEY REVISIONS**

**METASTATIC DISEASE**

- **M1a**
  - Pleural nodule(s), malignant pleural or pericardial effusion, contralateral nodule(s)

- **M1b**
  - Distant metastatic disease

**TUMOR (T) DESIGNATION**

- **Tumor descriptors:** T1-T4

- **Size**
  - Long-axis diameter used for measurement

- **Invasion**
  - Satellite nodule(s)
  - Same or different lobe as primary tumor

**IMAGING EVALUATION**

- CT is typically used to evaluate the primary tumor and delineate the extent of involvement

- MRI is beneficial in specific scenarios
  - Better diagnostic performance than CT in assessing locoregional invasion of the chest wall, mediastinum, and diaphragmatic pleura
  - Superior to CT in evaluating the heart, pericardium, and great vessels

- PET/CT is more accurate than CT or PET in delineating the extent of tumor involvement
  - CT: 68%
  - PET: 55%
  - PET/CT: 82%

- MRI vs. PET/CT:
  - In one study (Plathow et al), whole-body MRI was more accurate than PET/CT
  - Another study (Yi et al) revealed no significant differences between MRI and PET/CT in assessing T status

**T1 TUMOR**

<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>5-year Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodule &lt;2 cm</td>
<td>T1a</td>
<td>77%</td>
</tr>
<tr>
<td>Nodule &gt;2 cm but ≤3 cm</td>
<td>T1b</td>
<td>71%</td>
</tr>
</tbody>
</table>

**T2 TUMOR**

<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>5-year Survival</th>
</tr>
</thead>
</table>
| Tumor >3 cm but ≤5 cm surrounded by lung or Tumor ≤5 cm and
  - Invasion of visceral pleura
  - Involvement of main bronchus >2 cm from carina
  - Results in atelectasis of or post-obstructive pneumonia in less than entire lung | T2a | 58%             |
| Tumor >5 cm but ≤7 cm surrounded by lung or Tumor >5 cm but ≤7 cm and
  - Invasion of visceral pleura
  - Involvement of main bronchus >2 cm from carina
  - Results in atelectasis of or post-obstructive pneumonia in less than entire lung | T2b | 49%             |
**KEY FEATURES**

**T2 TUMORS**
- Tumor >3 but ≤7 cm
- Invasion of the visceral pleura
- Atelectasis of less than entire lung

**T3 TUMORS**
- Satellite nodule in same lobe
- Tumor >7 cm
- Invasion of the chest wall
- Atelectasis of entire lung

**T4 TUMOR**
- Tumor nodule(s) in ipsilateral lung but not same lobe as primary tumor
- Invasion of any of the following:
  - Mediastinum
  - Heart
  - Great vessels
  - Trachea
  - Esophagus
  - Recurrent laryngeal nerve
  - Carina
  - Vertebral body

**T3 TUMOR**

<table>
<thead>
<tr>
<th>T3 TUMOR</th>
<th>5-year Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite tumor nodule(s) in same lobe</td>
<td>45%</td>
</tr>
<tr>
<td>Any tumor &gt;7 cm in greatest diameter</td>
<td>35%</td>
</tr>
</tbody>
</table>
| Invasion of any of the following:  
  - Chest wall  
  - Diaphragm  
  - Phrenic nerve  
  - Mediastinal pleura  
  - Parietal pericardium | 41% |
| Tumor in main bronchus <2 cm from carina but not involving carina | 41% |
| Tumor of any size resulting in atelectasis of or post-obstructive pneumonia in entire lung | 41% |

**CHEST WALL INVASION IMAGING EVALUATION**

- **CT:**
  - Sensitivities between 38-87% and 40-90% have been reported
  - Osseous destruction with or without extension of tumor into the chest wall is the most reliable finding

- **MRI:**
  - Infiltration or disruption of normal extrapleural fat plane on T1WI or hyperintensity of parietal pleura on T2WI
  - Chest rib destruction on STIR
  - Fixation of tumor to chest wall during breathing on cine MR
**MEDIASTINAL INVASION**

**IMAGING EVALUATION**

- Invasion of mediastinal fat does not preclude resection
- Invasion of mediastinal structures such as the trachea, esophagus, and great vessels usually precludes resection
- CT vs. MRI:
  - CT: Sensitivity of 40-84% and specificity of 57-94%
  - MRI: One study (Ohno et al) showed higher accuracy, sensitivity, and specificity for MRA than CT and T1WI

**LYMPH NODE (N) DESIGNATION**

**IMAGING EVALUATION**

- Nodal descriptors: N0-N3
- Describes the presence or absence of intrathoracic lymph node involvement
- Size
  - Short-axis diameter typically used for measurement

- PET and PET/CT improve the detection of nodal involvement
  - Accuracy: 75-80%
  - Sensitivity: 70-75%
  - Specificity: 90-95%

- MRI:
  - Accuracy: 80-85%
  - Sensitivity: 75-83%
  - Specificity: 82-87%

- MRI vs. PET/CT:
  - STIR superior to PET/CT (Ohno et al)
  - No significant difference between whole-body MRI and PET/CT (Yi et al)
  - DW-MRI more accurate than PET/CT (Nomori et al)

**LYMPH NODE (N) DESIGNATION**

<table>
<thead>
<tr>
<th>Number of Nodal Groups Involved</th>
<th>5-year Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>N0</td>
<td>56%</td>
</tr>
<tr>
<td>N1</td>
<td>38%</td>
</tr>
<tr>
<td>N1a (single)</td>
<td>48%</td>
</tr>
<tr>
<td>N1b (multiple)</td>
<td>35%</td>
</tr>
<tr>
<td>N2</td>
<td>22%</td>
</tr>
<tr>
<td>N2a (single)</td>
<td>34%</td>
</tr>
<tr>
<td>N2b (multiple)</td>
<td>20%</td>
</tr>
<tr>
<td>N3</td>
<td>6%</td>
</tr>
<tr>
<td>N3</td>
<td>6%</td>
</tr>
</tbody>
</table>

**LYMPH NODE (N) DESIGNATION**

<table>
<thead>
<tr>
<th>Nodal Group</th>
<th>5-year Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>No lymphadenopathy</td>
<td>56%</td>
</tr>
<tr>
<td>Ipsilateral peripheral</td>
<td>38%</td>
</tr>
<tr>
<td>Ipsilateral hilar/interlobar</td>
<td>38%</td>
</tr>
<tr>
<td>Ipsilateral mediastinal</td>
<td>35%</td>
</tr>
<tr>
<td>Subcarinal</td>
<td>22%</td>
</tr>
<tr>
<td>Contralateral mediastinal</td>
<td>20%</td>
</tr>
<tr>
<td>Contralateral hilar/interlobar</td>
<td>16%</td>
</tr>
<tr>
<td>Contralateral peripheral</td>
<td>6%</td>
</tr>
<tr>
<td>Ipsilateral or contralateral supraclavicular</td>
<td>6%</td>
</tr>
</tbody>
</table>
Metastasis (M) Designation

- M descriptors: M0-M1
- Metastatic disease is present in approximately 40% of patients at the time of initial staging
- Most common sites:
  - Liver
  - Brain
  - Bone
  - Adrenal
- Presence of metastatic disease may preclude resection

Metastasis (N) Designation

- PET/CT:
  - More accurate than CT
  - Addition of PET/CT has been shown to alter management
  - Best for identifying lymph node and soft tissue metastases
- MRI:
  - Best at identifying brain, liver, and adrenal metastases
  - Chemical shift MR techniques can be used to distinguish adrenal metastases from benign adenomas

<table>
<thead>
<tr>
<th>Metastasis Type</th>
<th>M</th>
<th>5-Year Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleural or pericardial metastases</td>
<td>M1a</td>
<td>2%</td>
</tr>
<tr>
<td>Contralateral pulmonary nodule(s)</td>
<td>M1a</td>
<td>3%</td>
</tr>
<tr>
<td>Distant metastases</td>
<td>M1b</td>
<td>1%</td>
</tr>
</tbody>
</table>

Key Features

**M1a: Intrathoracic Metastases**
- Pleural effusion, thickening, and/or nodule(s)
- Pericardial effusion
- Nodule(s) in contralateral lung

**M1b: Distant Metastases**
- Brain
- Adrenal
- Liver
## TNM Staging System

<table>
<thead>
<tr>
<th></th>
<th>N0</th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1a</td>
<td>IA</td>
<td>IIA</td>
<td>IIA</td>
<td>IIB</td>
</tr>
<tr>
<td>T1b</td>
<td>IA</td>
<td>IIA</td>
<td>IIA</td>
<td>IIB</td>
</tr>
<tr>
<td>T2a</td>
<td>IB</td>
<td>IIA</td>
<td>IIA</td>
<td>IIB</td>
</tr>
<tr>
<td>T2b</td>
<td>IIA</td>
<td>IIIB</td>
<td>IIA</td>
<td>IIB</td>
</tr>
<tr>
<td>T3</td>
<td>IIIB</td>
<td>IIA</td>
<td>IIA</td>
<td>IIB</td>
</tr>
<tr>
<td>T4</td>
<td>IIIA</td>
<td>IIIA</td>
<td>IIIB</td>
<td>IIB</td>
</tr>
<tr>
<td>M1a</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
</tr>
<tr>
<td>M1b</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
</tr>
</tbody>
</table>

## Summary

- Lung cancer is the leading cause of cancer-related mortality in the United States.
- Accurate staging is crucial to the formulation of effective treatment strategies.
- Revisions to the TNM staging system are based on significant differences in patient survival.
- Radiologists should be familiar with the TNM staging system and understand the importance of specific imaging findings.

## Role of Imaging in Lung Cancer Staging

**Update and Controversial Topics**

**Brett W. Carter, MD**

[Image of MD Anderson Cancer Center]