Thoracic Imaging

What the oncologists need to know?

Warawut Sukkasem, M.D.
Department of Diagnostic and Therapeutic Radiology
Faculty of Medicine Ramathibodi Hospital Mahidol University

Outline
- Imaging principles
  - CXR
  - CT
- Clinical applications
  - Pulmonary nodule
  - Lung cancer
  - New terms for adenocarcinoma
    - AAH, AIS and MIA
  - Staging
    - Nodal classification

Chest radiograph

- X-ray beam passes through body
- Each structures attenuates X-ray beam differently
- Radiation received by detector varies according to these densities

Density
- Air
- Fat
- Soft tissue
- Bone/Calcification
- Metallic

Chest CT

- X-ray beam passes through body
- Each structures attenuates X-ray beam differently
- Radiation received by detector varies according to these densities

CT: x-ray profile is registered on CT detector
Computer reconstructs the raw CT data into an image
Intensity values (CT numbers) based on Hounsfield units (HU)

- Water = 0 HU
- Air = -1000 HU
- Fat = -60 to -120 HU
- Unenhanced soft tissue = 50 HU
- Bone = 1000 – 2000 HU

A 50-year-old smoker presents with acute chest pain.

A 6.0-cm mass at LUL with 1st rib invasion

A 65-year-old smoker presents with dyspnea and weight loss.

Tuberculoma
**Pulmonary nodule**

- Round intraparenchymal opacity
- ≤ 3 cm in diameter (>3 cm → mass)

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**Suspicious pulmonary nodule**

**Typical Radiographic Characteristics of Lung cancer**

- Diameter >2 cm
- Most common in the upper lobes
- Ill-defined, irregular, or spiculated margin
- Lobulated or irregular in shape
- Containing air bronchograms or bubbly luencies (pseudocavitation)
- Cavitation with a thick (> 15 mm) and nodular wall
- Cavitation without an air-fluid level
- Satellite nodules absent
- Calcification absent or not typical of a benign pattern
- Enhancement of ≥15 HU following contrast infusion
- Doubling time of 30-200 days

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**Margins and Contours**

- **Smooth**
- **Lobulated**
- **Irregular**
- **Spiculated**

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**Smooth margin**

- **Does not indicate benignity**
- 21% of smooth, sharply marginated nodule are malignant
- DDx: granuloma, hamartoma or benign tumor, carcinoid tumor, metastasis

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**Solitary metastasis from bladder cancer**

- Smoothly marginated, 1-cm peripheral nodule.
- Solitary metastases account for 3%-5% of all resected solitary pulmonary nodules

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**Differential diagnosis**

- Neoplasm
  - Benign: hamartoma, inflammatory pseudotumor, bronchogenic carcinoma, lymphoma (Hodgkin's), metastasis
  - Malignant: bronchogenic carcinoma, carcinoid tumor, lymphoma (non-Hodgkin's), metastasis

- Infection
  - Granuloma: Mycobacteria, fungi
  - Septic embolus: Bacteria (anaerobes, Staph, gram negative), fungi
  - Abscess: Bacteria (anaerobes, Staph, gram negative), fungi, Nocardia

- Inflammatory
  - Connective tissue: Wegener's granulomatosis, rheumatoid (necrobiotic) nodule
  - Arteriovenous malformation: Hematoma, Pulmonary infarct, Pulmonary artery aneurysm, Pulmonary venous varix

- Airway
  - Congenital lesion: Bronchogenic cyst, bronchial atresia, mucocele, infected bulla

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**Erasmus JJ. Radiographics 2000;20:43-58**
Lobulated Margin

- Uneven rate of growth
- Associated with malignancy
- 40% of smooth-edged lobulated nodule are malignant

Non small cell CA
(Erasmus JJ. Radiographics 2000;20:43-58)

Spiculated and irregular

- 88.5% of spiculated nodules are malignant
- Radial extension of malignant cells along interlobular septa, lymphatic, small airway or blood vessels

CT chest shows spiculated nodule with eccentric cavitation in the right upper lobe
Patho  NSCLC
(Erasmus JJ. Radiographics 2000;20:43-58)

Density and Internal Characteristics

- Calcification
- Fat
- Nodule attenuation
- Cavitation
- Air bronchogram or pseudocavitation

Webb WR. Thoracic imaging : pulmonary and cardiovascular radiology 2005;9

Popcorn calcification

Pulmonary hamartoma in 40-year-old man
(Erasmus JJ. Radiographics 2000;20:43-58)

Eccentric calcification

Eccentric calcification in lung adenocarcinoma
(Helen T. Winer-Muram, RSNA 2006;239:34-49)
Metastatic osteosarcoma in a 21-year-old man
(a) Close-up chest CT scan: a small, high-attenuation nodule in the left lower lobe
(b) 8 months later: interval growth of the nodule, which has high attenuation and a lobulated contour.
Resection ➞ metastatic osteosarcoma.

Nodule attenuation
- **Solid**
- **Subsolid**
  - Part-solid nodule (PSN)
  - Ground-glass nodule (GGN)

**Solid nodule**
- Most common type of SPNs
- Infectious process e.g. tuberculosis and mycoses
- Malignant nodule III e.g. adenocarcinoma, SCC, large cell CA, carcinoid tumor and metastasis

**Ground-glass nodule**
34% are due to malignant
(Risk increased if nodule > 1.5 cm or round)
DDx inflammatory nodule

**Part-solid**
40-50% are malignant
e.g. invasive adenocarcinoma
DDx inflammatory/infection

CT scan in an 81-year-old man
a 2.8 cm irregular, partly solid left upper lobe nodule with pleural tags.
FNAB ➞ adenocarcinoma

**Cavitation**
- May occur in necrotic malignant SPNs or inflammatory benign lesions e.g.
  - Abscess
  - Infectious granulomatous lesions
  - Wegener’s granulomatosis
  - Pulmonary infarction
- **Wall thickness**
  - Benign: smooth, thin wall (< 4-5 mm)
  - Malignant: Irregular, thick wall (> 15-16 mm)
(80% of cavitary lung cancer ➞ SCC)
Cavity

- Aspergillus: thin wall cavity nodule (pt with leukemia)
- SCCA: smoothly margimated nodule with eccentric cavitiation and thick wall

(Eason M, Radiographics 2000;20:43-56)

Lung adenocarcinoma

- Old term
  - BAC
- New terms
  - AAH
  - AIS
  - MIA

Lung adenocarcinoma

- Preinvasive lesions
  - AAH and AIS
- Minimally invasive adenocarcinoma
  - MIA
- Invasive adenocarcinoma
  - With lepidic, acinar, papillary, micropapillary, and solid predominant
-Variant group
  - Invasive mucinous adenocarcinoma

Atypical adenomatous hyperplasia (AAH)

- A localized small (≤ 5 mm)
- Proliferation of atypical type II pneumocytes and/or Clara cells lining the alveolar walls and respiratory bronchioles

Atypical adenomatous hyperplasia (AAH)

- On CT, AAH manifests as a small (≤ 5 mm), ground-glass nodule which could be either single or multiple
  - 100% 5-year disease-free survival

Adenocarcinoma in situ (AIS)

- A small (≤ 3 cm) glandular proliferation that has pure lepidic growth without the presence of stromal, vascular, or pleural invasion
- M/C AIS are nonmucinous, with a proliferation of type II pneumocytes and/or Clara cells,
- Rare are mucinous consisting of tall columnar goblet cells which produce mucin
Adenocarcinoma in situ (AIS)

- On CT, nonmucinous AIS manifests as a small ground-glass nodule
- However, nonmucinous AIS may present as a part-solid nodule due to focal collapsed alveoli or focal thickened alveolar septa
- Mucinous AIS manifests as a solid nodule or a consolidation
- 100% 5-year disease-free survival


Minimally invasive adenocarcinoma (MIA)

- On CT, nonmucinous MIA manifest as a part solid nodule with a solid component ≤ 5 mm
- In addition, mucinous MIA may manifest as a solid pulmonary
- 100% 5-year disease-free survival


Minimally invasive adenocarcinoma (MIA)

A 53-year-old woman presented with cough. A-C axial CT show multiple, bilateral, ground-glass and part-solid pulmonary nodules and a lobulated solid mass with internal air bronchogram (arrow head) at the left upper lobe. Note unaffected vessels through some nodules (arrow) at the right upper lobe. The pathology shows lepidic predominant invasive adenocarcinoma (LPA) with multiple foci of adenocarcinoma in situ (AIS). The molecular study shows EGFR mutation.

A 68-year-old woman with smoking history found multiple pulmonary nodules in the screening chest CT. A axial CT shows a small faint ground-glass nodule at the right lower lobe. The pathology showed atypical adenomatous hyperplasia (AAH). B axial CT shows a part-solid nodule with a small solid component. The pathology showed adenocarcinoma in situ (AIS). C axial CT shows a part-solid nodule with a small solid component and minimal pleural tags. The pathology showed minimally invasive adenocarcinoma (MIA).

Staging of Lung Cancer

- The 8th edition of the TNM Classification for lung cancer was published in late 2016
- Based on the proposals of the International Association for the Study of Lung Cancer (IASLC) International Staging Project

**TNM Classification**

- **T** (Primary tumor)
- **N** (Regional lymph node involvement)
- **M** (Intrathoracic or distant metastases)

**T Descriptors IASLC**

- **T1**
  - a ≤ 1 cm
  - b > 1 cm to < 2 cm
  - c > 2 cm to ≤ 3 cm

- **T2**
  - a > 3 cm to ≤ 4 cm
  - b > 4 cm to ≤ 5 cm

- **T3**
  - > 5 cm to ≤ 7 cm

- **T4**
  - > 7 cm

**TNM Classification**

**T- Primary Tumor**

- **Tx** Primary tumor cannot be assessed or tumor proven by presence of malignant cells in sputum or bronchial washings but not visualized by imaging or bronchoscopy
- **T0** No evidence of primary tumor
- **Tis** Carcinoma in situ
- **T1** Tumor ≤ 3 cm in greatest dimension surrounded by lung or visceral pleura without bronchoscopic evidence of invasion more proximal than the lobar bronchus (i.e., not in the main bronchus)
  - **T1a** Tumor ≤ 1 cm in greatest dimension
  - **T1b** Tumor >1 cm but ≤ 2 cm in greatest dimension
  - **T1c** Tumor >2 cm but ≤ 3 cm in greatest dimension

- **T1(mi)** Minimally Invasive Adenocarcinoma

**TNM Classification**

**T- Primary Tumor**

- **T2** Tumor >3 cm but ≤ 5 cm or tumor with any of the following features:
  - Involves main bronchus regardless of distance from the carina but without involvement of the carina
  - Invades visceral pleura
  - Associated with atelectasis or obstructive pneumonitis that extends to the hilar region, involving part or all of the lung
  - **T2a** Tumor >3 cm but ≤ 4 cm in greatest dimension
  - **T2b** Tumor >4 cm but ≤ 5 cm in greatest dimension

**TNM Classification**

**T- Primary Tumor**

- **T3** Tumor >5 cm but ≤ 7 cm in greatest dimension or associated with separate tumor nodule(s) in the same lobe as the primary tumor or directly invades any of the following structures: chest wall (including the parietal pleura and superior sulcus tumors), phrenic nerve, parietal pericardium
- **T4** Tumor >7 cm in greatest dimension or associated with separate tumor nodule(s) in a different ipsilateral lobe than that of the primary tumor or invades any of the following structures: diaphragm, mediastinum, heart, great vessels, trachea, recurrent laryngeal nerve, esophagus, vertebral body, and carina

**N Descriptors IASLC**

- **N0** No regional nodal metastasis
- **N1** Metastasis to ipsilateral bronchopulmonary or hilar nodes
- **N2** Metastasis to ipsilateral mediastinal nodes including subcarinal node
- **N3** Metastasis to
  - Contralateral mediastinal/hilar
  - Ipsilateral/contralateral supraclavicular/scalen nodes
Staging of Lung Cancer

TNM Classification

N - Regional lymph node involvement

<table>
<thead>
<tr>
<th>N</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nx</td>
<td>Regional lymph nodes cannot be assessed</td>
</tr>
<tr>
<td>N0</td>
<td>No regional lymph node metastasis</td>
</tr>
<tr>
<td>N1</td>
<td>Metastasis in ipsilateral peribronchial and/or ipsilateral hilar lymph nodes and intrapulmonary nodes, including involvement by direct extension</td>
</tr>
<tr>
<td>N2</td>
<td>Metastasis in ipsilateral mediastinal and/or subcarinal lymph node(s)</td>
</tr>
<tr>
<td>N3</td>
<td>Metastasis in contralateral mediastinal, contralateral hilar, ipsilateral or contralateral scalene, or supraclavicular lymph node(s)</td>
</tr>
</tbody>
</table>


M Descriptors IASLC

- M0: No distant metastasis
- M1a: Separate tumor nodule(s) in a contralateral lobe; tumor with pleural or pericardial nodule(s) or malignant pleural or pericardial effusion
- M1b: Single extrathoracic metastasis: This includes involvement of a single distant (nonregional) lymph node
- M1c: Multiple extrathoracic metastases in one or more organs


TNM Classification

M - Distant metastasis

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<tbody>
<tr>
<td>M0</td>
<td>No distant metastasis</td>
</tr>
<tr>
<td>M1</td>
<td>Distant metastasis present</td>
</tr>
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<td>M1b</td>
<td>Single extrathoracic metastasis: This includes involvement of a single distant (nonregional) lymph node</td>
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Regional node classification

1. SuprACLavicular node

1. SuprACLavicular zone nodes
These include low cervical, suprACLavicular and sternal notch nodes.
Upper border: lower margin of clavicle.
Lower border: clavicles and upper border of manubrium.
The midline of the trachea serves as border between 1R and 1L.

2. Upper paratracheal node

2R. Right Upper Paratracheal
Upper border: upper border of manubrium.
Lower border: intersection of caudal margin of innominate (left brachiocefalic) vein with the trachea.
2L. Left Upper Paratracheal
Upper border: upper border of manubrium.
Lower border: superior border of aortic arch.

3. Prevascular and Prevertebral nodes

3. Prevascular and Prevertebral nodes
Station 3 nodes are not adjacent to the trachea like station 2 nodes.
They are either:
3A anterior to the vessels or
3B behind the esophagus, which lies prevertebrally.

4. Right lower paratracheal

4R. Right Lower Paratracheal
Upper border: intersection of caudal margin of innominate (left brachiocefalic) vein with the trachea.
Lower border: lower border of azygos vein.
4R nodes extend to the left lateral border of the trachea.

4L. Left lower paratracheal

4L. Left Lower Paratracheal
4L nodes are lower paratracheal nodes that are located to the left of the left tracheal border, between a horizontal line drawn tangentially to the upper margin of the aortic arch and a line extending across the left main bronchus at the level of the upper margin of the left upper lobe bronchus.
These include paratracheal nodes that are located medially to the ligamentum arteriosum.
Station 3 (AP-window) nodes are located laterally to the ligamentum arteriosum.
5. Subaortic and 6. Para-aortic nodes

Subaortic (or aortic-pulmonary window) nodes are lateral to the ligamentum arteriosum or the aorta or left pulmonary artery and proximal to the first branch of the left pulmonary artery and lie within the mediastinal pleural envelope.

6. Para-aortic nodes
Para-aortic (ascending aorta or phrenic) nodes are located anteriorly and laterally to the ascending aorta and the aortic arch from the upper margin to the lower margin of the aortic arch.

7. Subcarinal nodes
Subcarinal nodes are located caudally to the carina of the trachea, but are not associated with the lower lobe bronchi or arteries within the lung. On the right they extend caudally to the lower border of the bronchus intermedius. On the left they extend caudally to the upper border of the lower lobe bronchus.

8. Paraesophageal node
Paraesophageal nodes are below the carinal nodes and extend caudally to the diaphragm.

9. Pulmonary ligament node
Pulmonary ligament nodes are lying within the pulmonary ligament, including those in the posterior wall and lower part of the inferior pulmonary vein. The pulmonary ligament is the inferior extension of the mediastinal pleural reflections that surround the hila.

10-14 Hilar, Lobar and Subsegmental nodes

These are all hilar nodes.

10. Hilar nodes
These include nodes adjacent to the main stem bronchus and hilar vessels. On the right they extend from the lower rim of the ayzygos vein to the interlobar region. On the left from the upper rim of the pulmonary artery to the interlobar region.

Normal lymph node

- Small size
- Reniform shape
- Fat hilum
Normal lymph node

Pathologic lymph node
- Enlargement
- Round shape
- Loss of fat hilum
- Enhancement
- Necrosis

Measurement

Short axis diameter
A = correct  
B = incorrect

Enlarged lymph node
- Node: Considered significant in size and suspicious for metastatic disease
  - Mediastinal lymph node: ≥ 1 cm in the short axis diameter

Stage N1
- A patient with right-sided lung cancer
- An enlarged right hilar lymph node (level 10) (arrow) measuring 15 mm in the short axis
**Stage N2**

- An enlarged (1.6-cm) right upper paratracheal lymph node (level 2) (arrowhead)
- An enlarged (1.5-cm) right lower paratracheal lymph node (level 4) (arrowhead)

**Stage N3**

- Axial PET/CT image of the chest
- A primary mass in the left lung (arrow) and a right lower paratracheal lymph node (arrowhead), both of which demonstrate intense radiotracer uptake
- Enlarged bilateral supraclavicular lymph nodes (arrows)

**Limitation of CT**

- Normal-size regional lymph nodes may prove to have metastases
- Nodal enlargement can be due to reactive hyperplasia or other non-malignant conditions

**CT vs PET**

- CT identifying mediastinal lymph node metastases of NSCLC
  - Sensitivity 51%
  - Specificity 85%
- F-18 FDG PET identifying mediastinal lymph node metastases of NSCLC
  - Sensitivity 74%
  - Specificity 85%

**PET for N Staging**

- PET/CT could be crucial in evaluating nodal sites that are inaccessible to mediastinoscopy, such as paraaortic and subaortic regions
Case 1

Where is the lesion?

CXR

5 Dec 2015

29 Apr 2016

A 2.4-cm part-solid nodule at LLL

T1c

Chest CT

No lymph node enlargement
No adrenal metastasis
No liver metastasis
No brain metastasis
No bone metastasis

N0 M0

Case 1

T1c N0 M0 = stage IA
Case 2

Where is the lesion?

CXR

7 Jan 2016
29 Apr 2016

Chest CT

A 6.0-cm mass at LUL with 1st rib invasion
T3

CT

Enlarged left hilar and interlobar lymph nodes
No adrenal metastasis
No bone metastasis
No brain metastasis

N1 M0

Case 2
T3 N1 M0 = Stage IIIA
Case 3

T4 N3 M1c = Stage IVB

Where is the lesion?

A 6.7-cm enhancing mass at RUL with RUL bronchus, SVC and mediastinal invasion

Chest CT

Multiple bilateral enlarged mediastinal lymph nodes
Adrenal metastasis
Multiple liver metastasis
Multiple bone metastasis

N3 M1c

Summary

- CXR and CT provide density information of the structures
  - CXR: air, fat, soft tissue, bone, metallic
  - CT: CT number
    - Water = 0 HU
    - Air = -1000 HU
    - Fat = -60 to -120 HU
    - Soft tissue = 50 HU
    - Bone = 1000 to 2000 HU
Summary

- **Suspicious pulmonary nodule**
  - Size > 2 cm
  - Upper lobe
  - Ill-defined, irregular, spiculated margin
  - Lobulated contour
  - Thick-walled cavity
  - Malignant calcification
  - Enhancement
  - Doubling time 30-200 days
  - Persistent subsolid nodule

Summary

- **New terms of lung adenocarcinoma**
  - Preinvasive lesion: AAH, AIS
  - MIA
- No longer use the old term BAC

Summary

- **The 8th edition of the TNM staging**
- **Intrathoracic lymph nodes**
  - Station and anatomical landmarks
  - Normal vs. pathologic lymph node
  - Primary tumor vs. nodal metastasis
  - Measurement

Thank You for Your Attention!