Imaging Techniques in the Evaluation of Pulmonary Parenchymal Neoplasms*

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Conventional PA and lateral chest radiographs continue to be the initial examination of choice to evaluate patients who are suspected of having a pulmonary parenchymal neoplasm. A lung lesion can be characterized as probably benign or malignant based on its radiographic appearance (size, shape, margins, presence of calcification, cavitation or air bronchograms, growth rate). A spiculated or lobulated lesion greater than 3 cm in size that is noncalcified is highly suspicious for malignancy. A lung lesion less than 3 cm in size with smooth borders that appears noncalcified on conventional radiographs should be examined by CT, including densitometry to detect calcification or fat, which indicates benignity. In patients with known lung cancer, CT can help to stage the tumor by indicating hilar or mediastinal involvement, or distant metastases. Currently, MR imaging has a limited role, but can be used as a “problem solving” modality for selected cases in evaluating pulmonary parenchymal neoplasms. (Chest 1992; 101:239-43)

A wide variety of imaging techniques are currently available to evaluate pulmonary parenchymal neoplasms. The selection of the most appropriate imaging option requires an understanding of the strengths, weaknesses, and complementary roles of these modalities in order to limit the number of radiologic examinations, patient inconvenience, and associated expense. This article will summarize the current role of conventional and cross-sectional imaging techniques in the detection, diagnosis, and management of pulmonary parenchymal neoplasms.

ROLE OF CONVENTIONAL IMAGING IN PULMONARY PARENCHYMA NEOPLASMS

Posteroanterior (PA) and lateral chest radiographs remain the standard examination for the initial evaluation of patients who are suspected of having a pulmonary parenchymal neoplasm. Radiographs are cost-effective, highly sensitive, and carry little or no risk. High kilovoltage (130-140 kVp) studies are preferred to radiography with a “standard” technique (110 kVp), since they provide a wider latitude and provide better penetration of the ribs, heart, mediastinum, and diaphragm. Centrally located endobronchial and peribronchial lesions are also seen more easily. Small calcifications in lung nodules may be more difficult to diagnose with high kVp technique, and in problematic cases a low kVp exposure (70-80 kVp) may be used to diagnose calcification with greater confidence.

Detection of a Pulmonary Neoplasm

A pulmonary parenchymal neoplasm is often detected initially as a lung nodule (round or oval opacity less than 3 cm in size) or a mass (an opacity of any shape greater than 3 cm in diameter) on a PA chest radiograph, and a lateral view may help to localize the lesion.

Patients with a subtle lung lesion or the suspicion of a nodule on plain chest radiographs may require further imaging examinations. Extrapulmonary “abnormalities” such as an artifact, eg, button, nipple shadow, skin blemish, rib, or pleural density may occasionally simulate lung pathology. Fluoroscopic examination with spot films, oblique or overpenetrated radiographic views, or repeat radiographs with nipple markers may be useful to verify an equivocal abnormality on plain chest radiographs.

When a lung nodule or mass is detected on a chest radiograph, comparison with previous studies is often helpful. If a nodule was present previously and has remained unchanged in size for two years or more, it can be considered benign and requires no further radiologic evaluation. If a nodule is new and noncalcified, has increased in size or is of indeterminate age (no old films available), further work-up is indicated to exclude cancer. Often, and in retrospect, a lesion can be identified on old radiographs that was overlooked or was not considered at first to be a significant abnormality. Under ideal conditions, a nodule in the lung periphery may be detectable when it is as small as 3 mm in diameter, but generally 1 cm has been accepted as the threshold for detecting a peripheral lung cancer. A central lesion is occasionally not visible

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Diagnosis of Benign vs Malignant Lesion

A lung nodule or mass can be characterized as probably benign or malignant based on its radiographic characteristics including size, shape, smoothness of margins, presence of calcification, cavitation or air bronchograms, growth rate, and the presence of additional lesions.

The size of a lung lesion is important not only because it determines visibility on radiography, but also because of the relationship of lesion size to malignancy. In one recent study, only 2 percent of benign solitary nodules were larger than 3 cm in diameter, and most benign lung lesions (68 percent) were 1.5 cm or smaller. However, 25 percent of lung cancers in the same study were between 5 and 15 mm in diameter. Thus, while the chance of malignancy may be relatively high in a lesion that is larger than 3 cm, there is still a substantial chance of cancer in smaller lesions as well. Lung metastases are 2 cm or less in diameter in 82 percent of cases, while the average diameter of hamartomas varies from 24 mm in women to 31 mm in men.

A spicular margin on plain films, or CT scans, is highly suspicious for malignancy (Fig 1); this finding generally represents direct tumor extension into the lung and/or a desmoplastic response to tumor exten-

Figure 1 (A, left). Posteroanterior chest radiograph demonstrates a subtle density just inferior to the anterior end of first left rib (arrow). (B, right). Chest CT scan shows a spiculated nodule in left upper lobe (arrow) which is responsible for the density seen on radiograph in (A). A diagnosis of adenocarcinoma was made with percutaneous fine needle aspiration biopsy of the nodule. Also note emphysematous bullae in both lungs (arrowhead).

Figure 2 (A, left). Posteroanterior chest radiograph shows a 2 cm lobulated nodule in right upper lobe (arrow). (B, right). CT scan shows the nodule to be noncalcified (arrow). When resected, the lesion was found to be a primary leiomyoma.
sion. A lobulated margin suggests uneven growth and occurs not only in primary carcinomas, and metastatic lesions, but also in hamartomas, and other benign growths (Fig 2), as well as in active tuberculous lesions. New focal nodularity, or a discrete mass in close association with apical fibrotic changes, suggests the possibility of a scar carcinoma.

Radiographically visible calcification in a lesion is highly indicative of malignancy. Dense central (target), diffuse or laminated calcification within a lung nodule is characteristic of a granuloma, while “popcorn calcification” suggests a hamartoma. A minority of carcinoid tumors in or near the central bronchi may also calcify or ossify. Eccentric calcifications within nodules are suspicious, since lung cancer can engulf pre-existing calcified granulomas. Subtle calcification within lung cancer can be appreciated much more readily with CT. Metastatic lesions in the lungs from osteogenic sarcoma, thyroid, breast, or gastrointestinal tract primaries may also calcify.

Cavitation may occur in both benign and malignant lung lesions, but a cavity with a thin wall (<4 mm in maximum thickness) is not likely to be malignant. The presence of air bronchograms traversing a nodule, as may be seen in bronchoalveolar cell carcinoma and lymphoma, cannot be relied upon to identify the nature of a lesion since air bronchograms are observed even more frequently in benign lesions.

Current hypotheses relative to the doubling times of pulmonary nodules refer to volumetric growth and not to absolute diameters of the lesions. Most malignant tumors in the lung have volume doubling times in the range of 30 to 490 days (mean 120 days). In general, benign nodules double much faster or more slowly than malignant nodules.

Plain chest radiographic findings showing a lung nodule or a mass can be supplemented by conventional tomography, computed tomography (CT), or magnetic resonance (MR) imaging. However, conventional tomography, a planar imaging technique that enhances visualization of selected structures by blurring overlapping structures, has now been replaced by CT in most centers.

**ROLE OF CT IN PULMONARY PARENCHYMAL NEOPLASMS**

CT provides better contrast resolution and greater tissue discrimination of densities when compared with plain chest radiography. The axial imaging format of CT also can show a pulmonary neoplasm without superimposition by other structures. CT can help to differentiate some benign from malignant lesions, based on calcium and/or fat content which points toward benignity. It can also be used to stage primary lung cancers preoperatively.

A pulmonary parenchymal nodule on chest radiographs which is not obviously calcified and is less than 3 cm in size, with smooth or lobulated borders, should undergo CT densitometry in an attempt to demonstrate calcification and to establish benignity. Calcification has been detected by CT in over 50 percent of benign lesions in which calcification could not be appreciated on conventional radiographs. High resolution CT images (1 mm to 3 mm in thickness) using narrow window settings are particularly useful for this purpose. The presence of calcification can be determined by calculating a “representative CT number” for the lung nodule under study. An average CT number that is greater than or equal to 164 Hounsfield units is usually associated with benignity. Zerhouni et al. have developed a CT reference phantom that reduces densitometric error and provides a scanner-independent standard for determining nodule calcification. For a diagnosis of benignity to be made, the amount of calcification in a lung nodule should be substantial and should represent over 10 percent of the nodule. The calcification should have a benign pattern (see above). Rarely, lung cancers may contain some calcification in an amorphous, punctate, or reticular pattern. On the other hand, CT demonstration of fat along with calcification in a smooth lung nodule which is less than 2.5 cm in diameter, makes the diagnosis of hamartoma nearly certain. Most lung metastases are noncalcified and are round and well circumscribed, but some metastases have infiltrating margins. On rare occasions a diffuse interstitial pattern in the lung can be seen on CT scans in association with lymphohematogenous metastases.

A small lung lesion may sometimes be missed by CT if it lies in a “skip area” between adjacent planar images, because of variations in the depth of suspended respiration or because of patient motion in

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<th>Table 1—<strong>Radiologic Criteria for Differentiating Malignant from Benign Pulmonary Opacities</strong></th>
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<tr>
<td><strong>More Likely Malignant</strong></td>
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<tr>
<td>- Opacity larger than 3 cm in diameter</td>
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<td>- Spiculated margins</td>
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<tr>
<td>- Noncalcified</td>
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<tr>
<td>- Increasing size (doubling time 30-490 days)</td>
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<tr>
<td><strong>More Likely Benign</strong></td>
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<tr>
<td>- Stable size for 2 years,† or doubling time less than 30 days</td>
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<td>- Benign pattern of calcification (see text)†</td>
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<td>- Well-circumscribed margins</td>
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<td>- Small (&lt;2 cm) size</td>
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<td>- Nearby satellite lesions</td>
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<td>- Cavitated with thin walls or with airfluid level</td>
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<tr>
<td><strong>Indeterminate or Noncontributory Factors</strong></td>
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<td>- Age of lesion is unknown (no prior radiographs)</td>
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<td>- Noncalcified, or eccentric calcification</td>
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<td>- 2-3 cm in size, with smooth margins</td>
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*The criteria in each section of this table are “additive” (eg, the presence of 2 or 3 criteria has greater impact than one alone).†Major criteria of benignancy.
Based on the findings from plain chest radiographs and CT, a lung lesion can be categorized as being likely to be malignant, benign, or indeterminate (Table 1). One can often suspect a lesion to be malignant, but it is far more difficult to definitively say it is benign, except in the setting of presence of benign pattern of calcification or demonstration of stability over time. Diagnostic confirmation can be accomplished by bronchoscopy with biopsy if the lesion is centrally located, or by transthoracic needle aspiration biopsy if it is in the lung periphery. Preoperative diagnosis of a nonresectable cancer or of a benign lesion may obviate the need for a thoracotomy.

CT can help to stage a lung cancer by showing direct chest wall, hilar, or mediastinal invasion by the primary tumor or by detecting regional (hilar or mediastinal) lymphadenopathy. The role of CT in staging small and presumably early peripheral lung cancers is controversial. Pearlberg et al.12 and Daly et al.13 believe that in a patient with a small discrete lung lesion (under 3 cm) and a normal mediastinum on plain chest radiographs, CT scan is not indicated since the likelihood of detecting mediastinal lymphadenopathy is low. Mathews et al.14 extend this criterion to peripheral lesions up to 4 cm in size, while Backer et al.15 believe that a patient with a discrete lung lesion of any size in whom the hila and mediastinum appear completely normal on plain chest radiographs should not require CT for further evaluation. Other investigators argue for the use of CT, suggesting that mediastinal adenopathy can be detected and/or a contralateral lung lesion or adrenal metastasis can be found in a sizable number of patients with peripheral lung primaries.16,17 Patients with centrally located lesions are more likely to benefit from a CT examination to demonstrate (or rule out) direct hilar or mediastinal invasion or metastatic adenopathy. Patients with unequivocal mediastinal lymphadenopathy on plain chest radiographs usually do not require CT for staging purposes.

**ROLE OF MR IMAGING IN PULMONARY PARENCHYMAL NEOPLASMS**

Magnetic resonance imaging currently has a limited role in evaluating pulmonary parenchymal neoplasms due to several factors. Motion degradation still is a significant problem with MR imaging in pulmonary parenchymal lesions. The limited availability of the equipment and the longer overall examination time of MRI as compared with CT have also restricted its use for evaluating pulmonary parenchymal lesions. The morphology of a nodule, its relationship to pulmonary fissures which may help in localization,18 and the presence of calcification are not shown as well with MRI as with CT. However, MRI can be useful as a problem-solving modality in selected patients. The coronal or sagittal imaging capability can help to determine cranial (Fig 3) or caudal extent of lesions which are located at the lung apices (eg, superior sulcus tumors) or at the bases. The superb soft tissue contrast of MR images may also be useful for determining chest wall involvement by peripheral pulmonary neoplasms. Magnetic resonance imaging can be of particular value when the distinction between a lung nodule and pulmonary vessels is uncertain by CT. For example, a pulmonary neoplasm can be distinguished from an arteriovenous malformation by the identification of blood flow within a vascular lesion on MRI.19 Similarly, MRI can be useful in differentiating a hilar mass or metastatic adenopathy from a large pulmonary artery in patients who present with a prominent hilum on chest radiographs. While CT is frequently tried first in such patients, MRI may be of assistance subsequently when the CT findings are inconclusive because vascular contrast enhancement is suboptimal or contrast administration is contraindicated.

**FIGURE 3 (A, left).** Posteroanterior chest radiograph shows a right apical mass with destruction of posterior portion of second rib (arrow). Mass was diagnosed as squamous cell carcinoma by fine needle aspiration biopsy. (B, center) CT scan shows the apical cancer (arrow), but superior extent is difficult to determine with axial images. (C, right). Coronal MR image demonstrates easily the superior extent of the mass (arrow).
ROLE OF OTHER IMAGING TECHNIQUES IN PULMONARY PARENCHYMAL NEOPLASMS

Chest radiographs can now be obtained with direct digital imaging, which appears to be the primary imaging modality of the future. With dual energy subtraction in association with a digital radiographic technique, selective evaluation of the lungs or the soft tissues without the presence of overlying rib shadows, or the detection and quantification of minute amounts of calcium, can now be accomplished.

The ultimate role of nuclear medicine scanning with gallium-67 citrate to evaluate primary lung cancers and hilar or mediastinal adenopathy is still subject to some disagreement. Opinions vary from not recommending the use of 67Ga in any circumstance to recommending it as a highly sensitive indicator of tumor spread. A number of authorities agree that 67Ga scans can be helpful in screening for metastases, except in the abdomen where colon contents may obscure focal concentrations of the radionuclide. In patients with bronchial carcinoids, iodine-131-meta-iodobenzyl guanidine (MIBG) may be used to locate this neuroendocrine tumor and ascertain regional tumor extension when it is present.

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