

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Staging of Bronchogenic Carcinoma

Variant 1: Non-small-cell lung carcinoma.

Radiologic Procedure	Rating	Comments	RRL*
CT chest with or without contrast (including upper abdomen)	9	CT with contrast is preferred if there are no strong contraindications.	☼☼☼☼
X-ray chest	8	Chest radiograph should be performed at the time of staging as baseline if no recent radiograph is available.	☼
FDG-PET whole body	8		☼☼☼☼
MRI head with contrast	7	Particularly if neurological symptoms are present. See statement regarding contrast in text under “Anticipated Exceptions.”	O
CT abdomen without and with contrast	5		☼☼☼☼
CT head with contrast	5	If MRI is contraindicated and neurological symptoms are present.	☼☼☼
Tc-99m bone scan whole body	5	Not necessary if PET has been done.	☼☼☼
MRI chest with contrast	3	Useful for evaluating chest wall invasion and for local staging of superior sulcus tumors.	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: Small-cell lung carcinoma.

Radiologic Procedure	Rating	Comments	RRL*
X-ray chest	9	Chest radiograph should be performed at the time of staging as baseline if no recent radiograph is available.	☼
CT chest with or without contrast (including upper abdomen)	9	CT with contrast is preferred if there are no strong contraindications.	☼☼☼☼
MRI head with contrast	8	See statement regarding contrast in text under “Anticipated Exceptions.”	O
FDG-PET whole body	7		☼☼☼☼
CT abdomen without and with contrast	5		☼☼☼☼
CT head with contrast	5	If MRI contraindicated and neurological symptoms are present.	☼☼☼
Tc-99m bone scan whole body	5	Not necessary if PET has been done.	☼☼☼
MRI chest with contrast	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

STAGING OF BRONCHOGENIC CARCINOMA

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Summary of Literature Review

Non-Small-Cell Lung Carcinoma

Staging

Staging of any tumor is done to determine the extent of disease. Staging information is important for two reasons: 1) to determine prognosis and 2) to select patients for surgical intervention and/or a different modality. The TNM staging system is widely used to classify lung tumors. In 1986 it was revised after epidemiologic evidence demonstrated improved survival following surgical resection in patients who had previously been classified as having unresectable disease [1]. In the TNM classification, “T” indicates the features of the primary tumor, “N” indicates metastasis to regional lymph nodes, and “M” refers to the presence or absence of distant metastases ([Appendix 1 and 2](#)).

The current Mountain classification [2] consist of four stages, which are defined in [Appendix 2](#). Stage I has been divided into two groups: IA and IB. Data have consistently shown a better outcome for patients with stage IA disease—that is, T1N0M0—than for any other subset. Survival rates are estimated to be approximately 60% in patients with clinical stage IA disease and only 38% for those in clinical stage IB. Stage IB is defined as patients with T2 tumors. Stage II is also subdivided into A and B groups. The survival rate for patients with stage IIA disease—that is, T1 lesions with involved hilar nodes (T1N1M0)—is higher than for those with stage IIB disease (T2N1M0 or T3N0M0). However, the former is a

small group of patients who are encountered rather infrequently.

Stage III is divided into IIIA and IIIB, where IIIB is considered unresectable disease, (ie, T4 and/or N3). In the current classification, tumors with limited invasion of the chest wall and mediastinum (T3) are considered to be potentially resectable provided that vital structures in the mediastinum, such as the great vessels, heart, and aerodigestive tract, are not involved. The designation T4 is now used to describe lesions with extensive invasion of the mediastinum or diaphragm, as well as tumors with satellite tumor nodule(s) within the ipsilateral primary-tumor lobe of the lung. In the current system, patients with ipsilateral mediastinal and subcarinal nodal metastasis (N2) are also considered to have resectable cancer. However, for the most part, only patients with limited ipsilateral mediastinal nodal disease fall into the operable category. These are usually cases in which the tumor is contained within the capsule of the lymph nodes and is limited to involvement of the lower mediastinal nodes. A category N3 was added to the TNM staging to refer to metastasis in the contralateral mediastinal, hilar, scalene or supraclavicular lymph nodes. N3 disease is considered to be unresectable. In the current classification, stage IV includes patients with evidence of distant metastasis (M1) away from the ipsilateral primary tumor lobe of the lung.

A number of imaging modalities have historically been used in staging lung cancer. These have included standard and conventional tomography as well as computed tomography (CT) and magnetic resonance imaging (MRI). In some instances, accurate staging and the determination of appropriate treatment for patients with lung cancer can be made noninvasively with imaging modalities alone, although in most cases some degree of surgical staging and biopsy evidence is also necessary.

Chest Radiographs

The need for appropriateness guidelines for routine chest radiographs in lung cancer appears to be a nonissue. The vast majority of primary lung cancers are initially detected on routine chest radiographs. There may be certain instances in which the chest radiograph alone is a sufficient imaging procedure for staging—for example, when an obvious metastatic bone lesion is detected or when large bulky contralateral mediastinal lymph nodes are present. However, numerous studies have shown that the chest radiograph lacks sensitivity in detecting mediastinal lymph node metastases and in detecting chest wall and mediastinal invasion [3].

Computed Tomography

CT has now become the major imaging modality of choice in the evaluation of patients with bronchogenic carcinoma. Numerous studies have shown that its value in staging is limited, because there are no morphologic criteria that would allow distinction between benign and malignant lymph nodes. It is certainly more sensitive than

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standard radiography [4], however, and it may serve as a guide to surgical management and in the determination of appropriate methods for surgical staging.

Traditionally, chest CT for staging of lung cancer is extended into the abdomen to include the adrenal glands. Whether this requires intravenous contrast material is debatable. Patz et al [5] addressed the question of whether administration of intravenous contrast material during CT of the thorax and upper abdomen (including the liver) changed the tumor stage and management compared with nonenhanced helical CT in 96 patients with newly diagnosed lung cancer. Although four of these patients were either upstaged or downstaged after intravenous contrast administration, there was no change in management. The authors concluded that contrast-enhanced CT extended to include the liver rarely adds to routine nonenhanced CT through the adrenal glands and does not influence management decisions.

Evaluation of Primary Tumor (the T Factor)

It is not always possible to distinguish T3 from T4 lesions with imaging studies. Lesions with chest wall invasion are classified as T3 lesions and are potentially resectable. Surgical resection, however, requires an en bloc resection of the pulmonary malignancy and the contiguous chest wall and is associated with an operative mortality in the range of 8%-15%. It is therefore important to determine preoperatively if chest wall invasion is present in order to select patients as operative candidates. Although CT provides information incrementally superior to that of radiographs, many of the findings described in the literature that are said to be associated with chest wall invasion have been shown to be neither sensitive nor specific. Webb et al [6] demonstrated a sensitivity of only 62% for CT in distinguishing T3 to T4 tumors from T0 to T2 tumors. Similarly, Glazer et al [7] found CT to be of limited value for assessing chest wall invasion, with a sensitivity of 87% and specificity of only 59%. CT was found to be more specific in assessing chest pain (94%) [7]. Some of the signs that have been described include pleural thickening adjacent to the tumor, encroachment on or increased density of subpleural fat, or an obtuse angle between the pulmonary mass and the pleural surface. Only the presence of a mass in the chest wall or definite rib destruction are helpful indicators of chest wall invasion.

Similarly, CT may be useful when extensive mediastinal invasion is present. Contrast-enhanced images may show vascular encasement and involvement of major mediastinal organs. However, CT is unable in some instances to distinguish contiguity of tumor with the mediastinum from actual invasion of the walls of vital mediastinal structures. In a study by Herman et al [8], the sensitivity of CT depended on the sign of mediastinal invasion that was used. It was only 40% for 90 degrees of contact between the mass and the mediastinal structure, and 44% if distortion of the mediastinal structure was present. Positive predictive values (PPVs) were low, and these authors concluded that CT was not useful in determining mediastinal invasion.

Evaluation of Nodal Metastasis (the N Factor)

CT is often the first-line method for assessing mediastinal nodes in bronchogenic carcinoma. Numerous studies have consistently documented improved survival of selected patients after resection of mediastinal nodal disease and, in most cases, adjuvant radiation therapy. The revised Mountain classification [2] considers patients with ipsilateral mediastinal lymph node metastasis (N2) as having potentially surgically resectable stage IIIA disease. Included in this group are patients with 1) intracapsular rather than extracapsular involvement and 2) positive nodes identified at thoracotomy after negative mediastinoscopy. In addition, early reports have indicated that even patients with gross and bulky ipsilateral nodal metastases (N2) may benefit from surgery if it is combined with neoadjuvant chemotherapy and radiation therapy. However, patients with contralateral mediastinal nodal involvement (N3) are considered to have unresectable stage IIIB disease.

Several studies have addressed the accuracy of CT in the staging of mediastinal nodal metastasis in lung cancer. More recent studies that have used total nodal sampling and the American Thoracic Society Lymph Node Classification have generally shown a low sensitivity of CT in detecting nodal metastasis.

A meta-analysis of mediastinal staging by CT [9] evaluated 20 studies dated 1991 through 2001 with a total of 3,438 patients, with the vast majority using a short-axis diameter >10 mm as the criterion for nodal positivity. Citing marked heterogeneity of the individual studies, the authors reported the pooled sensitivity and specificity of CT scanning as 57% and 82%, respectively, while the overall PPV and negative predictive values (NPV) of CT scanning were 56% and 86%, respectively. Furthermore, the authors concluded that there was no demonstrable improvement in accuracy over the past decade in spite of advances in CT technology.

In summary, controversy still exists about the value of CT scanning in staging the mediastinum in lung cancer. A negative CT scan for mediastinal adenopathy may provide useful information, particularly in institutions in which mediastinoscopy may not be available or preferred. If patients are selected immediately for thoracotomy without preceding mediastinoscopy, careful nodal sampling must be done at the time of surgery. Because of the low specificity of CT, enlarged lymph nodes must be biopsied for accurate staging. Despite the limited sensitivity and specificity of CT, it is used almost universally for staging the mediastinum in lung cancer. This use appears to be appropriate because of the additional information it provides, such as a map of enlarged nodes prior to mediastinoscopy, as well as information on enlarged nodes that are out of reach of the mediastinoscope or that are contralateral in position and suspect for N3 disease.

The issue of CT staging of the mediastinum in T1 lesions is controversial. T1 tumors are defined as lesions ≤ 3 cm in greatest diameter surrounded by lung or visceral pleura without evidence of invasion proximal to the lobar

bronchus. Several studies have suggested a low prevalence of mediastinal nodal metastatic disease with T1 cancers (5%-15%). Because of this low prevalence, it has been suggested that CT may not be necessary in such patients and that the preoperative staging should be limited to chest radiographs. However, Seely et al [10] found a 21% prevalence of nodal metastasis among 104 patients with T1 lesions. The sensitivity of CT was 77% for detecting these metastases, and the study's authors recommended that CT be performed in such patients. Pearlberg et al [11], in a study of 23 patients with T1 lesions, found only one patient who had CT evidence of noncurative disease. Because of the low yield, CT was not recommended. In a larger series of 63 patients, Duncan et al [12] found that 14% of patients with T1 lung cancers had inoperable disease correctly detected by CT. However, pathologic proof of inoperability was lacking. In summary, the issue remains controversial, and none of the studies appears to be definitive.

Evaluation of Distant Metastasis (the M Factor)

The role of CT in distinguishing extrathoracic metastasis from bronchogenic carcinoma is also controversial. There appears to be general agreement that CT of the thorax should include the adrenal glands, which are a frequent site of metastases from non-small-cell lung cancer (NSCLC). In a study of 91 autopsy-proven adrenal metastases from lung cancer, Allard et al [13] found that the sensitivity of CT was low (41%) but that the specificity was high (99%). They recommended CT but noted that patients with a negative CT had a 30% likelihood of adrenal metastasis. The other potential problem with screening the adrenal glands is the nonspecificity of the findings. This problem has been documented in later studies. Oliver et al [14] studied 330 patients with bronchogenic carcinoma, 33 of whom had adrenal masses. Only 25% had metastatic disease, and the remainder had adenomas. Adenomas can often be distinguished from metastases by their smaller size and low attenuation values. However, in many cases, additional imaging with MRI or percutaneous biopsy is necessary for diagnosis. A similar study by Hussain et al [15] confirmed the nonspecificity of adrenal masses in patients with nonadrenal primaries.

Bone scintigraphy has significant limitations in the detection of metastatic disease. Although it has high sensitivity, it is noted for very low specificity that ranges from 50%-60%. Bone scintigraphy should probably be limited to cases in which patients have specified clinical indicators of bone metastasis [16]. Routine cerebral imaging in the form of CT is recommended only for patients with stage III disease, particularly those with adenocarcinoma and large-cell carcinoma cell types [17].

Magnetic Resonance Imaging

Initial experience suggests that evaluation of the mediastinum with MRI is approximately equal to that of CT with regard to the staging of bronchogenic carcinoma [6]. However, a study by Webb et al [6] showed that MRI was significantly more accurate for detecting direct

mediastinal invasion. Other studies have confirmed the usefulness of MRI, particularly in the evaluation of chest wall invasion and the local staging of superior sulcus tumors. Heelan et al [18] showed an accuracy of MRI of 94% compared with 63% for CT in determining tumor invasion through the superior sulcus. Similarly, Padovani et al [19] showed that T1-weighted images had 90% sensitivity and 86% specificity in detecting chest wall invasion by lung cancer. MRI is particularly useful in determining certain parameters of unresectability for superior sulcus cancers, such as invasion of the vertebral body and involvement of the subclavian artery and brachial plexus. The general conclusion of these studies is that MRI has advantages in the assessment of both chest wall and mediastinal invasion.

Positron Emission Tomography

Initial studies of positron emission tomography (PET) imaging in lung cancer using 18-fluorodeoxyglucose (FDG) indicated that PET is clinically useful for staging lung carcinoma [20-26]. The multicenter randomized PLUS (PET in lung cancer) trial [27], comparing a group of 96 patients staged with conventional workup with a group of 92 patients staged with both conventional workup and PET, concluded that "addition of PET to conventional workup prevented unnecessary surgery in one out of five patients with suspected non-small-cell lung cancer." In a more recent study comparing PET to CT for nodal staging [28], Ebihara et al concluded that PET was more accurate than CT for N0, N2, and N3 disease, had a lower frequency of false-positive findings in the upper mediastinal nodes, and a lower frequency of false-negative findings in adenocarcinoma and false-positives in squamous cell carcinoma. However, addition of PET imaging in patients with negative brain CT or MRI does not appear to have much benefit. A recent study involving 287 patients with negative brain CT or MRI found four patients with positive PET findings. In all four patients brain metastases were excluded clinically [29].

The large body of evidence prompted several meta-analyses of the existing data. In a comprehensive review of current evidence, Toloza et al [9] pooled 18 studies conducted between 1994 and 2001 with a total of 1,045 evaluable patients. The authors found that the summary receiver operator characteristic (ROC) curve was significantly more accurate for PET than for CT ($p < 0.001$), with a pooled sensitivity of 88% and a specificity of 89%. The PPV and NPV values were 79% and 93%, respectively. A meta-analysis of 13 studies by Alongi et al [30] showed FDG-PET to be more accurate than CT in mediastinal lymph node staging of NSCLC.

Several studies compared the performance of FDG-PET with bone scintigraphy in patients with NSCLC [31] and in patients with all types of lung cancer [32,33]. In a prospective study of 48 patients with NSCLC, Hsia et al [31] demonstrated that the diagnostic sensitivity and accuracy of FDG-PET were 93.4% and 93.5%, respectively, compared to 92.5% and 72.5% for Tc-99m MDP bone scans. They concluded that FDG-PET has the

same sensitivity and a better accuracy than Tc-99m MDP bone scan to detect metastatic bone lesions in patients with NSCLC. In a retrospective study of 85 patients, Gayed et al [33] concluded that FDG-PET scans demonstrated significantly higher specificity and NPV than bone scans for evaluating bony metastases. A larger retrospective study in a group of 257 patients by Cheran et al [32] demonstrated the accuracies of PET and bone scan to be 94% and 85% ($p < 0.05$), sensitivity values 91% and 75%, and specificity values 96% and 95%, respectively. The authors concluded that given the improvement in accuracy and sensitivity with PET, bone scan could be eliminated from the staging evaluation.

Availability of PET has improved dramatically in recent years. With over 1,000 cameras installed in North America [34] in 2004, it is now feasible to include PET in the routine staging of lung carcinoma. PET may be particularly helpful in centers where mediastinoscopy is not readily available, and in patients with significant comorbid conditions who are borderline candidates for surgery, with locally advanced disease, solitary brain metastasis, and cases of local recurrence that might qualify for repeat operation [35,36].

There is a mounting body of data supporting the utility of FDG-PET in the treatment of patients with NSCLC. Kalff et al [37] investigated prospectively the impact of FDG-PET on clinical management of patients with NSCLC. FDG-PET scanning changed or influenced management decisions in 70 (67%) of their 105 patients, prompting them to conclude that patients who underwent FDG-PET were frequently spared unnecessary treatment, and management was more appropriately targeted. Sachs and Bilfinger [38] demonstrated in a study of 198 patients that systematic addition of FDG-PET had significant impact on patient management, altering diagnostic or therapeutic interventions in 72.2% and changing staging in 22.2% of patients. In a prospective randomized trial of patients with NSCLC, Herder et al [39] demonstrated that addition of PET to the initial staging significantly decreased the number of mediastinoscopies.

The growing evidence that PET is more accurate than CT in staging of NSCLC has prompted questions of its cost-effectiveness. Sloka et al [40] conducted a meta-analysis of 12 individual studies in order to predict the most cost-effective strategy for staging of NSCLC patients in Canada. They concluded that addition PET to CT is expected to save CA\$1,455 per person. A more recent study by Yap et al [41] calculated that routine FDG-PET scanning with selective mediastinoscopy would save AU\$2,128 per patient and would reduce inappropriate surgery.

Positron Emission Tomography/Computed Tomography

Since the resolution of PET imaging is relatively low, PET images are usually correlated visually with CT. The new integrated PET/CT technology is showing promise in staging lung carcinoma. Four recent studies [42-45] involving a total of 1,073 patients showed that PET/CT

ranged 42%-85% in sensitivity, 84%-100% in specificity, and 84%-94% in accuracy. Yi et al [45] and Shim et al [44] demonstrated that PET/CT improves the accuracy of staging compared to PET and CT obtained separately. However, a retrospective review by Lee et al [46] of 336 patients staged with PET (210) or PET/CT (126) demonstrated an increase in sensitivity (PET/CT 86%, PET alone 61%) at the price of decreased specificity (PET/CT 81%, PET alone 94%) and diminished accuracy (PET/CT 82%, PET alone 87%). The PPV of 69% for PET decreased to 56% for PET/CT, and the NPV of 92% for PET rose slightly to 95% for PET/CT. The authors concluded that improvements in PET technology have increased the sensitivity of integrated PET/CT at the cost of significantly decreased specificity and that noninvasive PET imaging is not ready to replace surgical staging in patients with NSCLC.

Small-Cell Lung Carcinoma

According to the recent analysis of the Surveillance, Epidemiology, and End Results database, small cell lung cancer (SCLC) now accounts for about 14% of all new cases of lung cancer [47]. It is more aggressive than the non-small-cell form, with median survival of 2-4 months if untreated. Rather than the TNM classification, the staging system widely applied is based on studies of the Veterans Administration Lung Study Group. In this system, patients are classified as having either limited disease (ie, tumor confined to one hemithorax and to the regional lymph nodes) or extensive disease (ie, tumor beyond this area in contralateral lung or extrathoracic sites). Extensive disease is present in 60%-80% of patients newly diagnosed with SCLC [46]. Conventional staging for extrathoracic metastasis in patients with SCLC includes CT of the abdomen, CT or MRI of the head, and bone scintigraphy [48,49]. A bone marrow biopsy may be omitted for patients with normal blood counts, normal lactate dehydrogenase level, and negative result on bone scan [50]. Other routine staging procedures include liver function tests and complete blood counts.

Noninvasive imaging is generally recommended only in patients who have abnormal routine screening tests. Hirsch et al [51] compared CT and ultrasound (US) in staging the abdomen in patients with SCLC. They found that CT was more sensitive than US and showed 50% of patients with extensive disease compared with 39% by US. Twenty percent of patients were restaged as a result of the CT findings. These authors, however, recommended that CT of the abdomen only be performed in patients with biochemical abnormalities. In regard to the search for central nervous system (CNS) metastasis, again the recommendation is that routine brain CT or MRI only be done for patients involved in clinical study protocols. The remainder should be limited to patients with symptomatic or clinically detectable CNS metastasis. Habets et al [52] attempted to determine the value of routine CT of the brain in patients with SCLC compared to neurologic findings. Of a total of 57 patients, both with and without neurologic symptoms, only four had brain metastases, and three of these patients had the metastases

confirmed by CT. In the one negative patient, CT was later found to be positive. All of these patients were symptomatic or had positive neurologic examinations. Of the 54 non-neurologically symptomatic patients, no metastases were detected on CT.

As with NSCLC, skeletal metastasis may be evaluated with bone scanning. Although highly sensitive, bone scanning has a low specificity in SCLC, as it does in NSCLC. Two recent retrospective studies have suggested that PET can replace bone scintigraphy in staging patients with all types of lung cancer [32,33]. Screening is best limited to patients with symptoms or abnormal biochemical profiles. A preliminary study of 25 patients conducted by Jelinek et al [53] examined the value of MRI in staging SCLC. The MRI resulted in a change in staging in five of the 25 patients. These patients were found to have extensive disease. Additional metastases were found in the bone and liver as a result of the MRI. However, details on the clinical studies on these patients are not available in this study, and the work appears to be too preliminary to allow any recommendation on the use of MRI in the staging of SCLC.

There is mounting evidence that PET is useful in staging SCLC patients. Several prospective studies each in a relatively small group of patients [54-56] concluded that FDG-PET has high sensitivity for SCLC. In a larger prospective study, Brink et al [57] demonstrated greater sensitivity of FDG-PET than that of CT for detecting extrathoracic lymph node involvement (100% vs 70%, specificity 98% vs 94%) and greater sensitivity and specificity for detecting distant metastases except to the brain (98% vs 83%, specificity 92% vs 79%). However, FDG-PET was significantly less sensitive than cranial MRI/CT in detecting brain metastases (46% vs 100%, specificity 97% vs 100%). In their sample, FDG-PET resulted in stage migration in 14 (12%) of 120 patients. All stage changes affected management. Only one patient was incorrectly staged by PET due to failure to detect brain metastases. The authors concluded that FDG-PET will improve staging and may reduce the number of tests and invasive procedures in patients with SCLC. Most recently, Niho et al [58] demonstrated that FDG-PEG changed management in 8% of their 63 SCLC patients and recommended FDG-PET as an initial staging tool for patients with this disease.

In a prospective study of patients with SCLC, Fischer et al [59] compared integrated PET/CT with standard staging (CT, bone scintigraphy, and bony marrow biopsy). In their group of 34 patients PET/CT resulted in changes of stage in 17%. Sensitivities for standard staging, PET, and PET/CT were 79%, 93%, and 93%, and specificities were 100%, 83%, and 100%, respectively. This group concluded that addition of integrated PET/CT could simplify and even improve staging in patients with SCLC.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of

manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m²), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m². For more information, please see the [ACR Manual on Contrast Media](#) [60].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria[®] [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
⊕	<0.1 mSv	<0.03 mSv
⊕ ⊕	0.1-1 mSv	0.03-0.3 mSv
⊕ ⊕ ⊕	1-10 mSv	0.3-3 mSv
⊕ ⊕ ⊕ ⊕	10-30 mSv	3-10 mSv
⊕ ⊕ ⊕ ⊕ ⊕	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).

Supporting Document(s)

- [ACR Appropriateness Criteria® Overview](#)
- [Procedure Contrast Information](#)
- Evidence table under review

References

1. Mountain CF. A new international staging system for lung cancer. *Chest* 1986; 89(4 Suppl):225S-233S.
2. Mountain CF. Revisions in the International System for Staging Lung Cancer. *Chest* 1997; 111(6):1710-1717.
3. Bragg DG. The diagnosis and staging of primary lung cancer. *Radiol Clin North Am* 1994; 32(1):1-14.
4. Heavey LR, Glazer GM, Gross BH, Francis IR, Orringer MB. The role of CT in staging radiographic T1N0M0 lung cancer. *AJR* 1986; 146(2):285-290.
5. Patz EF, Jr., Erasmus JJ, McAdams HP, et al. Lung cancer staging and management: comparison of contrast-enhanced and nonenhanced helical CT of the thorax. *Radiology* 1999; 212(1):56-60.
6. Webb WR, Gatsonis C, Zerhouni EA, et al. CT and MR imaging in staging non-small cell bronchogenic carcinoma: report of the Radiologic Diagnostic Oncology Group. *Radiology* 1991; 178(3):705-713.
7. Glazer HS, Duncan-Meyer J, Aronberg DJ, Moran JF, Levitt RG, Sagel SS. Pleural and chest wall invasion in bronchogenic carcinoma: CT evaluation. *Radiology* 1985; 157(1):191-194.
8. Herman SJ, Winton TL, Weisbrod GL, Towers MJ, Mentzer SJ. Mediastinal invasion by bronchogenic carcinoma: CT signs. *Radiology* 1994; 190(3):841-846.
9. Toloza EM, Harpole L, McCrory DC. Noninvasive staging of non-small cell lung cancer: a review of the current evidence. *Chest* 2003; 123(1 Suppl):137S-146S.
10. Seely JM, Mayo JR, Miller RR, Muller NL. T1 lung cancer: prevalence of mediastinal nodal metastases and diagnostic accuracy of CT. *Radiology* 1993; 186(1):129-132.
11. Pearlberg JL, Sandler MA, Beute GH, Madrazo BL. T1N0M0 bronchogenic carcinoma: assessment by CT. *Radiology* 1985; 157(1):187-190.
12. Duncan KA, Gomersall LN, Weir J. Computed tomography of the chest in T1NoMo non-small cell bronchial carcinoma. *Br J Radiol* 1993; 66(781):20-22.
13. Allard P, Yankaskas BC, Fletcher RH, Parker LA, Halvorsen RA, Jr. Sensitivity and specificity of computed tomography for the detection of adrenal metastatic lesions among 91 autopsied lung cancer patients. *Cancer* 1990; 66(3):457-462.
14. Oliver TW, Jr., Bernardino ME, Miller JI, Mansour K, Greene D, Davis WA. Isolated adrenal masses in nonsmall-cell bronchogenic carcinoma. *Radiology* 1984; 153(1):217-218.
15. Hussain S, Belldegrun A, Seltzer SE, Richie JP, Abrams HL. CT diagnosis of adrenal abnormalities in patients with primary non-adrenal malignancies. *Eur J Radiol* 1986; 6(2):127-131.
16. Michel F, Soler M, Imhof E, Perruchoud AP. Initial staging of non-small cell lung cancer: value of routine radioisotope bone scanning. *Thorax* 1991; 46(7):469-473.
17. Salbeck R, Grau HC, Artmann H. Cerebral tumor staging in patients with bronchial carcinoma by computed tomography. *Cancer* 1990; 66(9):2007-2011.
18. Heelan RT, Demas BE, Caravelli JF, et al. Superior sulcus tumors: CT and MR imaging. *Radiology* 1989; 170(3 Pt 1):637-641.
19. Padovani B, Mouroux J, Seksik L, et al. Chest wall invasion by bronchogenic carcinoma: evaluation with MR imaging. *Radiology* 1993; 187(1):33-38.
20. MacManus MP, Hicks RJ, Matthews JP, et al. High rate of detection of unsuspected distant metastases by pet in apparent stage III non-small-cell lung cancer: implications for radical radiation therapy. *Int J Radiat Oncol Biol Phys* 2001; 50(2):287-293.
21. Marom EM, McAdams HP, Erasmus JJ, et al. Staging non-small cell lung cancer with whole-body PET. *Radiology* 1999; 212(3):803-809.
22. Patz EF, Jr., Goodman PC. Positron emission tomography imaging of the thorax. *Radiol Clin North Am* 1994; 32(4):811-823.
23. Patz EF, Jr., Lowe VJ, Goodman PC, Herndon J. Thoracic nodal staging with PET imaging with 18FDG in patients with bronchogenic carcinoma. *Chest* 1995; 108(6):1617-1621.
24. Scott WJ, Gobar LS, Terry JD, Dewan NA, Sunderland JJ. Mediastinal lymph node staging of non-small-cell lung cancer: a prospective comparison of computed tomography and positron emission tomography. *J Thorac Cardiovasc Surg* 1996; 111(3):642-648.
25. Steinert HC, Hauser M, Allemann F, et al. Non-small cell lung cancer: nodal staging with FDG PET versus CT with correlative lymph node mapping and sampling. *Radiology* 1997; 202(2):441-446.
26. Wahl RL, Quint LE, Greenough RL, Meyer CR, White RI, Orringer MB. Staging of mediastinal non-small cell lung cancer with FDG PET, CT, and fusion images: preliminary prospective evaluation. *Radiology* 1994; 191(2):371-377.
27. van Tinteren H, Hoekstra OS, Smit EF, et al. Effectiveness of positron emission tomography in the preoperative assessment of patients with suspected non-small-cell lung cancer: the PLUS multicentre randomised trial. *Lancet* 2002; 359(9315):1388-1393.
28. Ebihara A, Nomori H, Watanabe K, et al. Characteristics of advantages of positron emission tomography over computed tomography for N-staging in lung cancer patients. *Jpn J Clin Oncol* 2006; 36(11):694-698.
29. Posther KE, McCall LM, Harpole DH, Jr., et al. Yield of brain 18F-FDG PET in evaluating patients with potentially operable non-small cell lung cancer. *J Nucl Med* 2006; 47(10):1607-1611.
30. Alongi F, Ragusa P, Montemaggi P, Bona CM. Combining independent studies of diagnostic fluorodeoxyglucose positron-emission tomography and computed tomography in mediastinal lymph node staging for non-small cell lung cancer. *Tumori* 2006; 92(4):327-333.
31. Hsia TC, Shen YY, Yen RF, Kao CH, Changlai SP. Comparing whole body 18F-2-deoxyglucose positron emission tomography and technetium-99m methylene diphosphate bone scan to detect bone metastases in patients with non-small cell lung cancer. *Neoplasma* 2002; 49(4):267-271.
32. Cheran SK, Herndon JE, 2nd, Patz EF, Jr. Comparison of whole-body FDG-PET to bone scan for detection of bone metastases in patients with a new diagnosis of lung cancer. *Lung Cancer* 2004; 44(3):317-325.
33. Gayed I, Vu T, Johnson M, Macapinlac H, Podoloff D. Comparison of bone and 2-deoxy-2-[18F]fluoro-D-glucose positron emission tomography in the evaluation of bony metastases in lung cancer. *Mol Imaging Biol* 2003; 5(1):26-31.
34. Machac J. Cardiac positron emission tomography imaging. *Semin Nucl Med* 2005; 35(1):17-36.
35. Detterbeck FC, Falen S, Rivera MP, Halle JS, Socinski MA. Seeking a home for a PET, part 2: Defining the appropriate place for positron emission tomography imaging in the staging of patients with suspected lung cancer. *Chest* 2004; 125(6):2300-2308.
36. Weder W, Schmid RA, Bruchhaus H, Hillinger S, von Schulthess GK, Steinert HC. Detection of extrathoracic metastases by positron emission tomography in lung cancer. *Ann Thorac Surg* 1998; 66(3):886-892; discussion 892-883.
37. Kalf V, Hicks RJ, MacManus MP, et al. Clinical impact of (18)F fluorodeoxyglucose positron emission tomography in patients with non-small-cell lung cancer: a prospective study. *J Clin Oncol* 2001; 19(1):111-118.
38. Sachs S, Bilfinger TV. The impact of positron emission tomography on clinical decision making in a university-based multidisciplinary lung cancer practice. *Chest* 2005; 128(2):698-703.
39. Herder GJ, Kramer H, Hoekstra OS, et al. Traditional versus up-front [18F] fluorodeoxyglucose-positron emission tomography staging of non-small-cell lung cancer: a Dutch cooperative randomized study. *J Clin Oncol* 2006; 24(12):1800-1806.
40. Sloka JS, Hollett PD, Mathews M. Cost-effectiveness of positron emission tomography for non-small cell lung carcinoma in Canada. *Med Sci Monit* 2004; 10(5):MT73-80.
41. Yap KK, Yap KS, Byrne AJ, et al. Positron emission tomography with selected mediastinoscopy compared to routine mediastinoscopy offers cost and clinical outcome benefits for pre-operative staging of non-small cell lung cancer. *Eur J Nucl Med Mol Imaging* 2005; 32(9):1033-1040.

42. Kim BT, Lee KS, Shim SS, et al. Stage T1 non-small cell lung cancer: preoperative mediastinal nodal staging with integrated FDG PET/CT—a prospective study. *Radiology* 2006; 241(2):501-509.
43. Kim YK, Lee KS, Kim BT, et al. Mediastinal nodal staging of nonsmall cell lung cancer using integrated 18F-FDG PET/CT in a tuberculosis-endemic country: diagnostic efficacy in 674 patients. *Cancer* 2007; 109(6):1068-1077.
44. Shim SS, Lee KS, Kim BT, et al. Non-small cell lung cancer: prospective comparison of integrated FDG PET/CT and CT alone for preoperative staging. *Radiology* 2005; 236(3):1011-1019.
45. Yi CA, Lee KS, Kim BT, et al. Efficacy of helical dynamic CT versus integrated PET/CT for detection of mediastinal nodal metastasis in non-small cell lung cancer. *AJR* 2007; 188(2):318-325.
46. Lee BE, von Haag D, Lown T, Lau D, Calhoun R, Follette D. Advances in positron emission tomography technology have increased the need for surgical staging in non-small cell lung cancer. *J Thorac Cardiovasc Surg* 2007; 133(3):746-752.
47. Page NC, Read WL, Thierney RM. The epidemiology of small cell lung carcinoma. *Proc Annu Meet Am Soc Clin Oncol* 2002; 21:1216. Abstract.
48. Simon GR, Wagner H. Small cell lung cancer. *Chest* 2003; 123(1 Suppl):259S-271S.
49. Jackman DM, Johnson BE. Small-cell lung cancer. *Lancet* 2005; 366(9494):1385-1396.
50. Argiris A, Murren JR. Staging and clinical prognostic factors for small-cell lung cancer. *Cancer J* 2001; 7(5):437-447.
51. Hirsch FR, Osterlind K, Jensen LI, et al. The impact of abdominal computerized tomography on the pretreatment staging and prognosis of small cell lung cancer. *Ann Oncol* 1992; 3(6):469-474.
52. Habets JM, van Oosterhout AG, ten Velde GP, Wilmink JT, Twijnstra A. Diagnostic value of CT in the detection of brain metastasis in small cell lung cancer patients. *J Belge Radiol* 1992; 75(3):179-181.
53. Jelinek JS, Redmond J, 3rd, Perry JJ, et al. Small cell lung cancer: staging with MR imaging. *Radiology* 1990; 177(3):837-842.
54. Bradley JD, Dehdashti F, Mintun MA, Govindan R, Trinkaus K, Siegel BA. Positron emission tomography in limited-stage small-cell lung cancer: a prospective study. *J Clin Oncol* 2004; 22(16):3248-3254.
55. Hauber HP, Bohuslavizki KH, Lund CH, Fritscher-Ravens A, Meyer A, Pforte A. Positron emission tomography in the staging of small-cell lung cancer: a preliminary study. *Chest* 2001; 119(3):950-954.
56. Schumacher T, Brink I, Mix M, et al. FDG-PET imaging for the staging and follow-up of small cell lung cancer. *Eur J Nucl Med* 2001; 28(4):483-488.
57. Brink I, Schumacher T, Mix M, et al. Impact of [18F]FDG-PET on the primary staging of small-cell lung cancer. *Eur J Nucl Med Mol Imaging* 2004; 31(12):1614-1620.
58. Niho S, Fujii H, Murakami K, et al. Detection of unsuspected distant metastases and/or regional nodes by FDG-PET in LD-SCLC scan in apparent limited-disease small-cell lung cancer. *Lung Cancer* 2007.
59. Fischer BM, Mortensen J, Langer SW, et al. A prospective study of PET/CT in initial staging of small-cell lung cancer: comparison with CT, bone scintigraphy and bone marrow analysis. *Ann Oncol* 2007; 18(2):338-345.
60. American College of Radiology. *Manual on Contrast Media*. Available at: http://www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

Appendix 1. TNM Descriptors

Primary Tumor (T)

Stage	Definition
TX	Primary tumor cannot be assessed, or tumor proven by the presence of malignant cells in sputum or bronchial washings but not visualized by imaging or bronchoscopy.
T0	No evidence of primary tumor.
Tis	Carcinoma <i>in situ</i> .
T1	Tumor 3 cm in greatest dimension, surrounded by lung or visceral pleura, without bronchoscopic evidence of invasion more proximal than the lobar bronchus* (ie, not in the main bronchus).
T2	Tumor with any of the following features of size or extent: >3 cm in greatest dimension. Involves main bronchus, 2 cm distal to the carina. Invades the visceral pleura.
T3	Tumor of any size that directly invades any of the following: chest wall (including superior sulcus tumors), diaphragm, mediastinal pleura, parietal pericardium; or tumor in the main bronchus <2 cm distal to the carina, but without involvement of the carina; or associated atelectasis or obstructive pneumonitis of the entire lung.
T4	Tumor of any size that invades any of the following: mediastinum, heart, great vessels, trachea, esophagus, vertebral body, carina; or tumor with a malignant pleural or pericardial effusion† or with satellite tumor nodule(s) within the ipsilateral primary-tumor lobe of the lung.

Regional Lymph Nodes (N)

Stage	Definition
NX	Regional lymph nodes cannot be assessed.
N0	No regional lymph node metastasis.
N1	Metastasis to ipsilateral peribronchial and/or ipsilateral hilar lymph nodes, and intrapulmonary nodes involved by direct extension of the primary tumor.
N2	Metastasis to ipsilateral mediastinal and/or subcarinal lymph node(s).
N3	Metastasis to contralateral mediastinal, contralateral hilar, ipsilateral or contralateral scalene, or supraclavicular lymph node(s).

Distant Metastasis (M)

Stage	Definition
MX	Presence of distant metastasis cannot be assessed.
M0	No distant metastasis.
M1	Distant metastasis present.‡
*The uncommon superficial tumor of any size with its invasive component limited to the bronchial wall, which may extend proximal to the main bronchus, is also classified as T1.	
†Most pleural effusions associated with lung cancer are due to tumor. However, there are a few patients in whom multiple cytopathologic examinations of pleural fluid show no tumor. In these cases, the fluid is non-bloody and is not an exudate. When these elements and clinical judgment dictate that the effusion is not related to the tumor, the effusion should be excluded as a staging element, and the patient's disease should be staged T1, T2, or T3. Pericardial effusion is classified according to the same rules.	
‡Separate metastatic tumor nodule(s) in the ipsilateral non-primary-tumor lobe(s) of the lung are also classified M1.	

Appendix 2. Stage Grouping*

Stage	TNM Subset
0	Carcinoma <i>in situ</i>
IA	T1N0M0
IB	T2N0M0
IIA	T1N1M0
IIB	T2N1M0
	T3N0M0
IIIA	T3N1M0
	T1N2M0
	T2N2M0
	T3N2M0
IIIB	T4N0M0
	T4N1M0
	T4N2M0
	T1N3M0
	T2N3M0
	T3N3M0
IV	T4N3M0
	Any T, Any N, Any MI

*Staging is not relevant for occult carcinoma, designated TXN0M0.