

CHEST[®]

THE CARDIOPULMONARY
AND CRITICAL CARE JOURNAL

FOR PULMONOLOGISTS, CARDIOLOGISTS, CARDIOTHORACIC SURGEONS,
CRITICAL CARE PHYSICIANS, AND RELATED SPECIALISTS

Seeking a Home for a PET, Part 1: Defining the Appropriate Place for Positron Emission Tomography Imaging in the Diagnosis of Pulmonary Nodules or Masses

Frank C. Detterbeck, Steven Falen, M. Patricia Rivera, Jan S. Halle and Mark A.
Socinski

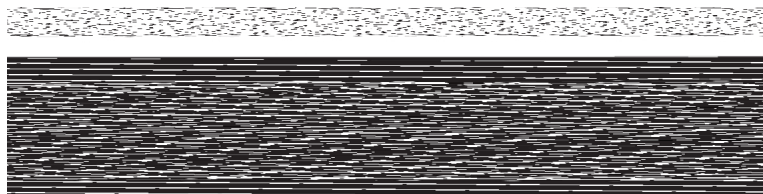
Chest 2004;125:2294-2299
DOI: 10.1378/chest.125.6.2294

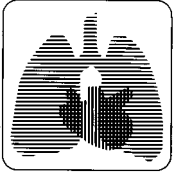
This information is current as of February 6, 2007

The online version of this article, along with updated information and services, is
located on the World Wide Web at:

<http://www.chestjournal.org/cgi/content/full/125/6/2294>

CHEST is the official journal of the American College of Chest Physicians. It has been published monthly since 1935. Copyright 2005 by the American College of Chest Physicians, 3300 Dundee Road, Northbrook IL 60062. All rights reserved. No part of this article or PDF may be reproduced or distributed without the prior written permission of the copyright holder. ISSN: 0012-3692.





reviews

Seeking a Home for a PET, Part 1*

Defining the Appropriate Place for Positron Emission Tomography Imaging in the Diagnosis of Pulmonary Nodules or Masses

Frank C. Detterbeck, MD, FCCP; Steven Falen, MD, PhD;
M. Patricia Rivera, MD, FCCP; Jan S. Halle, MD; and
Mark A. Socinski, MD, FCCP†

There is a growing experience with positron emission tomography (PET) in patients with pulmonary nodules or masses. As PET imaging becomes more widely available, it is important to thoughtfully define when application of this technology is warranted. Review of the literature to date suggests that PET imaging for diagnosis of pulmonary lesions is most useful in patients who have a low or intermediate risk of lung cancer as determined by an evaluation of symptoms, risk factors, and radiographic appearance. There is little role for PET in diagnosis in patients with a very low or a high risk of lung cancer, and there is little role in patients with lesions < 1 cm in diameter, or lesions suspected to be an infection, a bronchioloalveolar carcinoma, or a typical carcinoid tumor. (CHEST 2004; 125:2294–2299)

Key words: diagnosis; lung cancer; positron emission tomography; solitary pulmonary nodule

Abbreviations: BAC = bronchioloalveolar carcinoma; CXR = chest radiograph; F-18 FDG = [2-¹⁸F]2-fluoro-2-deoxy-D-glucose; FN = false-negative; FP = false-positive; PET = positron emission tomography

Positron emission tomography (PET) is an exciting imaging modality in patients with suspected lung cancer. Other imaging studies rely primarily on a demonstration of altered anatomy, such as lymph node or adrenal enlargement, whereas the basis of PET imaging is a difference in metabolism between normal and malignant cells. PET imaging can reveal

foci of lung cancer that are not seen by other imaging tests,^{1–3} which led to the approval of PET imaging for the diagnostic and staging workup of patients with lung cancer by the Centers for Medicare and

For related article see page 2300

Medicaid Services (formerly known as the Health Care Financing Administration) in the United States in 1998. PET imaging systems have become much more widely available, and their use in patients with non-small cell lung cancer has become fairly common in many communities.

The most commonly used radiotracer for PET imaging of lung cancers is [2-¹⁸F]fluoro-2-deoxy-D-glucose (F-18 FDG).⁴ Many tumor cells demonstrate an accelerated glucose metabolic rate,⁵ and therefore an increased rate of glucose (and F-18 FDG) uptake compared with normal cells.⁶ Intracellularly, F-18 FDG is then phosphorylated to F-18 FDG-6-phosphate by hexokinase, an enzyme that also has increased activity in tumor cells compared

*From the Division of Cardiothoracic Surgery, Department of Surgery (Dr. Detterbeck); Department of Radiology (Dr. Falen); Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine (Dr. Rivera); Department of Radiation Oncology (Dr. Halle); and Division of Medical Oncology, Department of Internal Medicine (Dr. Socinski), University of North Carolina at Chapel Hill, Chapel Hill, NC.

†Members of the Multidisciplinary Thoracic Oncology Program, University of North Carolina at Chapel Hill.
Manuscript received April 14, 2003; revision accepted September 4, 2003.

Reproduction of this article is prohibited without written permission from the American College of Chest Physicians (e-mail: permissions@chestnet.org).

Correspondence to: Frank C. Detterbeck, MD, FCCP, Division of Cardiothoracic Surgery, Medical School Wing C, Room 354 CB# 7065, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-7065; e-mail: fdetter@med.unc.edu

with normal cells.⁷ Furthermore, many malignant cells demonstrate a decreased rate of dephosphorylation compared with normal cells.⁸ As a result, F-18 FDG-6-phosphate accumulates within the tumor cells and allows for imaging.

Like any new technology, however, we must delineate under what circumstances it is useful and when it adds little. Having a clear understanding of when to use PET imaging is particularly important because of the cost of this modality. Furthermore, although some scan findings are clearly positive or negative, in many cases there are equivocal areas of uptake. The cost of additional scans to follow-up equivocal results is significant, and should be considered together with the cost of the PET study itself.⁹ These considerations make it important to be sure the PET scan was indicated in the first place.

BACKGROUND

How Should We Determine Who Should Have a PET?

Some authors have advocated PET for all patients with a pulmonary abnormality.¹⁰ However, most clinicians involved with the care of patients would accept that a pulmonary lesion should not circumvent a careful clinical evaluation. This entails an assessment of symptoms, the medical history, and risk factors for lung cancer. This allows some thought to be given to the likely diagnosis—and to the likely stage—if lung cancer is suspected. Consistent with this approach is the recommendation for a selective use of PET imaging by several authors.^{4,11–14}

To determine when a PET scan is useful, we must define when it is likely to change the management approach. The first step is to estimate the likelihood that a PET scan finding will be positive (or negative), which depends primarily on the prevalence of the clinical condition being investigated. If the prevalence of the clinical condition is very low (*ie*, < 5%), then it is difficult to justify PET imaging because the chance of finding a clinical condition that requires a change in management is very low. In addition, the likelihood of a positive (or negative) PET result also depends on the likelihood that the PET scan will be positive (or negative) when the clinical condition is actually present (or absent). This is measured by the sensitivity (if the clinical condition is present) and the specificity (if the clinical condition is absent). Sensitivity is the probability that the test result will, in fact, be positive in a population of patients, all of which have the condition in question. Specificity is the chance that the test result will, in fact, be negative in a different population, none of whom have the condition in question. Thus, these measures

are based on patient populations that are defined after the fact by the true disease status.

For a particular patient, however, whether a positive (or negative) PET result will end up affecting the management is primarily related to whether a positive (or negative) PET result correlates reliably with the clinical condition in question being present (or absent). If the reliability of a positive (or negative) result is too low to be trusted with confidence, then other tests will be necessary, making the PET scan superfluous. The reliability of a positive or negative result is known as the false-positive (FP) rate or false-negative (FN) rate. The FP rate is the number of FP findings divided by all positive results; the FN rate is the number of FN findings divided by all negative results. Thus, these parameters indicate the percentage of all positive (or negative) results that are false results. These measures are often expressed in an indirect manner as the positive predictive value (or negative predictive value). (The FP and FN rates should not be confused with the FP fraction and FN fraction, which are defined as 1 minus the specificity and 1 minus the sensitivity, respectively.)

Thus, whether the incidence of an unexpected result is high enough to justify a PET scan depends on the prevalence of the clinical condition as well as the sensitivity and specificity of the test. How the results of the test will be interpreted, however, depends on the FP rate (if the test result is positive) or the FN rate (if the test result is negative). This latter point must be emphasized: interpretation of a PET result in a particular patient requires the use of the FP (or FN) rate, not sensitivity or specificity.

Exceptions and Specific Situations

It is important to exclude certain specific situations in which characteristics of PET imaging limit the usefulness of this test (Table 1). A PET scan is primarily useful to differentiate a chronic benign condition from a cancer. When the patient's history, symptoms, or radiographic findings strongly suggest the possibility of infection, there is little role for PET imaging because an infectious nodule is very likely to be positive on PET imaging.^{2,15–18} In such a situa-

Table 1—Clinical Situations in Which PET Imaging Has Limited Utility for the Detection of Cancer

Clinical Situation	Reason
Infection	High FP rate
BAC	High FN rate
Typical carcinoid tumor	High FN rate
Comorbidities preventing treatment	No effect on management

tion, one should proceed directly to a test that is likely to diagnose the causative organism, because a specific diagnosis will need to be established in order to direct the appropriate antibiotic therapy in most instances of infectious nodules (as opposed to an infiltrate, which can be treated empirically). Methods to identify a causative organism may include placement of a tuberculosis skin test (purified protein derivative), a serum cryptococcal antigen level, or a bronchoscopy with transbronchial brushing or BAL.

In patients in whom the presence of a bronchioalveolar carcinoma (BAC) is considered to be a possibility, there is little role for PET imaging, because PET results are often falsely negative in cases of BAC.^{2,15,19–22} In addition, PET findings are often negative in cases of typical carcinoid tumors.^{23,24} Although both typical carcinoid tumors and BAC are low-grade carcinomas, there is ample evidence that these tumors do progress, metastasize, and are eventually lethal if not resected at an early stage.^{25,26}

Some patients have such severe comorbid conditions or poor performance status that they are not candidates for treatment, thus rendering PET imaging superfluous. However, specific arguments for PET imaging can be made in certain situations. For example, despite a high likelihood of lung cancer, there may be a reluctance to proceed with an invasive procedure to confirm the diagnosis or stage in a very-poor-risk patient unless a test such as PET imaging can make the likelihood of lung cancer very high (> 95%). However, such specific situations should be viewed as exceptions and cannot be used to justify PET scanning for the diagnosis of a pulmonary nodule or mass in general.

Other Issues Associated With the Usefulness of PET

Defining the role of PET scanning is complicated by the need for a histologic or cytologic diagnosis. No matter how reliable PET is for determining that malignant cells are present, it cannot determine the cell type and will not replace the need for microscopic examination of the malignant cells (except under unusual circumstances). If biopsy of a particular area will be required for diagnosis anyhow, PET imaging of this area may do little to alter the diagnostic approach.

Finally, it is important to be clear about the question that PET imaging is expected to address. PET can be used to gain information about the diagnosis of the primary tumor, to gain information about the likelihood of mediastinal node involvement (intrathoracic stage), and to discover distant

metastases (extrathoracic stage) in patients suspected to have lung cancer. This article addresses the role of PET for diagnosis of a pulmonary nodule, whereas the role of PET in staging of lung cancer is discussed in Part 2.²⁷ A PET scan will potentially address all of these issues, and any one of these issues by itself can be a valid reason to get this test. However, we must be careful not to use arguments for one issue to justify PET imaging when the clinical issue is actually something else. Thus, a thoughtful approach to the use of PET is complex, and requires consideration of a variety of issues and test parameters.

THE ROLE OF PET FOR DIAGNOSIS

Estimating the Likelihood of Lung Cancer

The approach to patients with a pulmonary lesion is determined to a large extent by the likelihood that a lesion in a particular patient is a lung cancer. The risk can be divided into several groups, for example as proposed in Table 2. Many factors influence the estimation of the likelihood of lung cancer, and a full discussion of these is beyond the scope of this article. Patient-related factors include the smoking history (approximately 2,000% increased risk in patients with a history of smoking compared with a lifelong nonsmoker).²⁸ The risk diminishes after cessation of smoking, but never reaches that of a nonsmoker (200 to 300% increased risk 20 years after cessation of smoking compared with a lifelong nonsmoker, corrected for other factors).²⁸ The risk of lung cancer is increased 400% if the patient has a significant amount of obstructive airway disease or a first-degree relative with lung cancer.²⁸ The risk is increased approximately 50% in women (corrected for other factors), whereas secondhand smoke increases the risk approximately 20 to 40%.²⁸ More importantly, the risk increases substantially by age (corrected for other factors). A previous, successfully treated lung cancer imparts a high risk of a new lung cancer (approximately 2% per year).²⁹ Radiographic factors include the rapidity of appearance of the lesion as well as the border characteristics. A spiculated lesion carries approximately an 80% chance of

Table 2—Proposed Categories of the Likelihood of Lung Cancer in Patients With a Pulmonary Lesion

Likelihood Category	Likelihood of Lung Cancer, %
Very low	< 5
Low	5–20
Intermediate	20–80
High	> 80

malignancy, a lobulated lesion approximately 60%, whereas a lesion with indistinct borders is more typical of an inflammatory process.²⁸

A combination of the clinical presentation, history, and risk factors, and the radiographic appearance of the abnormality on CT scan provides an estimate of the likelihood of lung cancer. Although these components can be combined in a complex Bayesian formula,³⁰ this is of little practical use, and most clinicians simply take stock of the entire picture to estimate the likelihood of lung cancer. Obviously this involves a great deal of judgment, taking into account many factors, which makes a multidisciplinary discussion the ideal forum to review the characteristics and make this estimate. Clinical practice suggests that this process is fairly accurate in estimating the likelihood of lung cancer.³¹

Patients With a Very Low and Low Likelihood of Lung Cancer

It is difficult to justify the use of PET imaging in patients who are believed to have a very low likelihood (< 5%) of having lung cancer as estimated by an assessment of risk factors, radiographic findings, and clinical presentation. The major clinical issue is to rule out cancer. It is true that the specificity of PET scanning is fairly high (*ie*, the chance of a negative PET result if the lesion is, in fact, benign). Furthermore, a negative PET result in an individual patient can be relied on with confidence because the FN rate of PET imaging for lesions ≥ 1 cm is quite low. However, cancer has already been ruled out to a high degree by the estimation of the likelihood of cancer. The chance of finding a lung cancer is so low that it is hard to justify further workup, especially using a test that costs as much as a PET scan. However, it seems reasonable in such situations to obtain a follow-up chest radiograph (CXR) [or CT scan] in 6 months, 12 months, and 24 months to provide further assurance that the lesion is benign.

In patients with a lesion that is estimated to have a low likelihood (5 to 20%) of being malignant, further workup to rule out cancer is warranted if this can be accomplished. PET is an excellent modality in this setting, provided the lesion is ≥ 1 cm and not likely to be an infection, BAC, or a carcinoid tumor. The sensitivity of PET (96%) is very high (chance of a positive result if the lesion is cancer), and the specificity (74%) is good (chance of a negative result if the lesion is benign), as shown in a meta-analysis.⁴ Furthermore, either a positive or a negative result in an individual patient can be trusted to a high degree. The FN rate of PET for lesions that are ≥ 1 cm is approximately 8 to 10%.^{12,32} Further follow-up of a negative PET result with a CXR or a CT scan in 6

months, 12 months, and 24 months seems reasonable, however. Similarly, the FP rate of PET is low (8 to 10%).^{12,32}

Patients with a low likelihood of lung cancer who have a lesion < 1 cm represent a conundrum. A test that would reliably decrease the possibility of lung cancer would be very useful. Although there are anecdotal reports of PET detecting cancers that are several millimeters in size, very few patients with lesions < 1 cm have been included in published series, and therefore the FN rate of PET scans for such lesions remains undefined.⁴ Anecdotal cases, no matter how striking, have no relevance in the definition of a thoughtful general policy. In one study,¹⁰ an FN rate of 18% was reported for lesions < 1.5 cm. Therefore, a rational approach in these patients involves either follow-up CT scans in 3 months, 6 months, 12 months, and 24 months or an excisional biopsy, and PET imaging for lesions < 1 cm in low-likelihood patients is not justified at this time.

Patients With an Intermediate Likelihood of Lung Cancer

Patients with a lesion having an intermediate likelihood of lung cancer would clearly benefit from a test that would move the patient into either a very low-likelihood or a high-likelihood category. Either result would define the course of further workup or follow-up that should be taken. If the lesion is ≥ 1 cm, PET is an ideal test because of a low FN rate (8%) and FP rate (8%) in this situation.³² If the PET scan finding is negative, a follow-up CXR or CT scan in 6 months, 12 months, and 24 months is useful to provide further assurance that the lesion is benign. If the PET finding is positive, further workup consistent with a high-likelihood category is warranted. This recommendation for PET imaging in patients with an intermediate likelihood of lung cancer after a clinical assessment and a CT scan is consistent with the conclusions reached in a recent detailed cost-effectiveness analysis (PET was recommended if the probability of lung cancer was 20 to 70%).¹⁴

Patients with an intermediate likelihood of lung cancer and a lesion < 1 cm represent a difficult situation. A positive PET scan result would certainly move the patient to a high-likelihood category, although the chance of this result (sensitivity) may be diminished in smaller lesions.¹⁰ However, the treating physicians should first determine what would be done in the face of a negative PET result. A PET scan can only be justified if the physician and the patient would be comfortable with an observation approach after a negative PET result. Because the FN rate of a PET scan for lesions < 1 cm is poorly defined (but likely to be 20 to 30%),¹⁰ a negative

Table 3—Role of PET for Diagnosis, Excluding Lesions That Are Suspicious for BAC or Carcinoid

Likelihood Category	Lesion Size, cm	Recommended Imaging Study
Very low		CXR or CT in 6, 12, or 24 mo
Low	< 1	CT in 3, 6, 12, or 24 mo
Low	≥ 1	PET
Intermediate	< 1	CT in 3, 6, 12, or 24 mo
Intermediate	≥ 1	PET
High		Staging as dictated by presentation*

*See Part 2 of this review.²⁷

PET scan result may not avert the need for a definitive diagnosis via an excisional biopsy (ideally using a thoracoscopic approach). The only alternative would be careful follow-up (eg, CT in 3 months, 6 months, 12 months, and 24 months). It is unlikely that a transthoracic needle aspiration (TTNA) will be useful in such situations because it also carries a high FN rate (20 to 30% overall, but likely higher in small lesions).

Patients With a High Likelihood of Lung Cancer

In patients who have a high likelihood of cancer, there is little role for PET for diagnosis. Although PET might make the likelihood of lung cancer even higher by intense uptake, the need to obtain a tissue diagnosis in most cases will render this aspect of the PET scan superfluous. Moreover, if a PET study result was, in fact, negative, it is likely that most physicians would be uncomfortable trusting this result in the face of highly suggestive clinical and radiographic features. PET may still be indicated for patients with a high likelihood of cancer for further definition of the extent of disease, but this is a different issue than to confirm the diagnosis. The role of PET for staging is discussed in Part 2 of this review.²⁷

CONCLUSION: WHO NEEDS A PET?

Recommendations for the use of PET imaging in the diagnosis of a pulmonary nodule are summarized in Table 3. Evaluating whether a patient would benefit from a PET scan starts with an assessment of the symptoms and risk factors for lung cancer, a review of sequential CXRs, and an examination of the chest CT scan. This allows an estimation to be made about the likelihood of lung cancer and the size of the lesion. There is no role for PET imaging in patients with a very low ($\leq 5\%$) likelihood of lung cancer. Patients with a low (5 to 20%) or an intermediate likelihood (20 to 80%) of lung cancer and a

lesion that is ≥ 1 cm should undergo PET imaging. Interpretation of the PET result is clear in patients with a lesion ≥ 1 cm, because the FN rate is defined and is approximately 5 to 10%, indicating that lung cancer can be ruled out with a reasonable degree of reliability. Patients with a lesion that is < 1 cm are not likely to benefit from a PET scan, although it may be reasonable to proceed with a PET scan in intermediate-risk patients provided the physician and the patient are willing to observe the lesion if the scan result is negative (although the FN rate is likely to be 20 to 30%). A positive PET result does not necessarily prove that the lesion is lung cancer, but further evaluation should be carried out as if it were until the diagnosis has been proven by a definitive biopsy. In patients who are estimated to have a high likelihood ($> 80\%$) of having lung cancer, there is little role of PET for diagnosis, although PET imaging has utility in defining the stage of cancer, as is discussed in Part 2 of this review.²⁷

REFERENCES

- 1 Scott WJ, Gobar LS, Terry JD, et al. 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; 111:642–648
- 2 Guhlmann A, Storck M, Kotzerke J, et al. Lymph node staging in non-small cell lung cancer: evaluation by [¹⁸F]FDG positron emission tomography (PET). *Thorax* 1997; 52:438–441
- 3 Valk PE, Pounds TR, Hopkins DM, et al. Staging non-small cell lung cancer by whole-body positron emission tomographic imaging. *Ann Thorac Surg* 1995; 60:1573–1582
- 4 Gould M, Maclean C, WG K, et al. Accuracy of positron emission tomography for diagnosis of pulmonary nodules and mass lesions: a meta analysis. *JAMA* 2001; 285:914–924
- 5 Warburg O. On the origin of cancer cells. *Science* 1956; 123:309–314
- 6 Flier J, Mueckler M, Usher P, et al. Elevated levels of glucose transport and transporter messenger RNA are induced by ras or src oncogenes. *Science* 1987; 235:1492–1495
- 7 Monakhov NK, Neistadt EL, Shavlovskil MM, et al. Physicochemical properties and isoenzyme composition of hexokinase from normal and malignant human tissues. *J Natl Cancer Inst* 1978; 61:27–34
- 8 Weber G, Cantero A. Glucose-6-phosphatase activity in normal, precancerous and neoplastic tissues. *Cancer Res* 1955; 15:105–108
- 9 Herder GJM, Verboom P, Smit EF, et al. Practice, efficacy and cost of staging suspected non-small cell lung cancer: a retrospective study in two Dutch hospitals. *Thorax* 2002; 57:11–14
- 10 Dewan NA, Shehan CJ, Reeb SD, et al. Likelihood of malignancy in a solitary pulmonary nodule: comparison of Bayesian analysis and results of FDG-PET scan. *Chest* 1997; 112:416–422
- 11 Weder W, Schmid RA, Bruchhaus H, et al. Detection of extrathoracic metastases by positron emission tomography in lung cancer. *Ann Thorac Surg* 1998; 66:886–893
- 12 Fischer BM, Mortensen J, Højgaard L. Positron emission tomography in the diagnosis and staging of lung cancer: a

- systematic, quantitative review. *Lancet Oncol* 2001; 2:659–666
- 13 Dietlein M, Weber K, Gandjour A, et al. Cost-effectiveness of FDG-PET for the management of potentially operable non-small cell lung cancer: priority for a PET-based strategy after nodal-negative CT results. *Eur J Nucl Med* 2000; 27:1598–1609
 - 14 Gould MK, Sanders GD, Barnett PG, et al. Cost-effectiveness of alternative management strategies for patients with solitary pulmonary nodules. *Ann Intern Med* 2003; 138:724–735
 - 15 Lowe VJ, Fletcher JW, Gobar L, et al. Prospective investigation of positron emission tomography in lung nodules. *J Clin Oncol* 1998; 16:1075–1084
 - 16 Dewan NA, Gupta NC, Redepenning LS, et al. Diagnostic efficacy of PET-FDG imaging in solitary pulmonary nodules: potential role in evaluation and management. *Chest* 1993; 104:997–1002
 - 17 Dewan NA, Reeb SD, Gupta NC, et al. PET-FDG imaging and transthoracic needle lung aspiration biopsy in evaluation of pulmonary lesions: a comparative risk-benefit analysis. *Chest* 1995; 108:441–446
 - 18 Bury T, Dowlati A, Paulus P, et al. Evaluation of the solitary pulmonary nodule by positron emission tomography imaging. *Eur Respir J* 1996; 9:410–414
 - 19 Scott WJ, Schwabe JL, Gupta NC, et al. Positron emission tomography of lung tumors and mediastinal lymph nodes using [¹⁸F]fluorodeoxyglucose. *Ann Thorac Surg* 1994; 58:698–703
 - 20 Higashi K, Seki H, Taniguchi M, et al. Bronchioloalveolar carcinoma: false-negative results on FDG-PET [abstract]. *J Nucl Med* 1997; 38(Suppl):79P
 - 21 Kim B-T, Kim Y, Lee KS, et al. Localized form of bronchioloalveolar carcinoma: FDG PET findings. *AJR Am J Roentgenol* 1998; 170:935–939
 - 22 Higashi K, Ueda Y, Seki H, et al. Fluorine-18-FDG PET imaging is negative in bronchioloalveolar lung carcinoma. *J Nucl Med* 1998; 39:1016–1020
 - 23 Chin R Jr, Ward R, Keyes JW Jr, et al. Mediastinal staging of non-small-cell lung cancer with positron emission tomography. *Am J Respir Crit Care Med* 1995; 152:2090–2096
 - 24 Gupta NC, Maloof J, Gunel E. Probability of malignancy in solitary pulmonary nodules using fluorine-18-FDG and PET. *J Nucl Med* 1996; 37:943–948
 - 25 Detterbeck FC, Jones DR, Funkhouser WK Jr. Bronchioloalveolar carcinoma. In: Detterbeck FC, Rivera MP, Socinski MA, et al, eds. *Diagnosis and treatment of lung cancer: an evidence-based guide for the practicing clinician*. Philadelphia, PA: W. B. Saunders, 2001; 394–407
 - 26 Kiser AC, Detterbeck FC. Carcinoid and mucoepidermoid tumors. In: Detterbeck FC, Rivera MP, Socinski MA, et al, eds. *Diagnosis and treatment of lung cancer: an evidence-based guide for the practicing clinician*. Philadelphia, PA: W. B. Saunders, 2001; 379–393
 - 27 Detterbeck F, Falen S, Rivera M, et al. 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; 125:2300–2308
 - 28 Rivera MP, Detterbeck FC, Loomis DP. Epidemiology and classification of lung cancer. In: Detterbeck FC, Rivera MP, Socinski MA, et al, eds. *Diagnosis and treatment of lung cancer: an evidence-based guide for the practicing clinician*. Philadelphia, PA: W. B. Saunders, 2001; 25–44
 - 29 Detterbeck FC, Jones DR, Funkhouser WK Jr. Satellite nodules and multiple primary cancers. In: Detterbeck FC, Rivera MP, Socinski MA, et al, eds. *Diagnosis and treatment of lung cancer: an evidence-based guide for the practicing clinician*. Philadelphia, PA: W. B. Saunders, 2001; 437–449
 - 30 Gurney JW, Lyddon DM, McKay JA. Determining the likelihood of malignancy in solitary pulmonary nodules with Bayesian analysis: Part II; Application. *Radiology* 1993; 186:415–422
 - 31 Swensen SJ, Silverstein MD, Edell ES, et al. Solitary pulmonary nodules: clinical presentation model versus physicians. *Mayo Clin Proc* 1999; 74:319–329
 - 32 Detterbeck FC, Rivera MP. Clinical presentation and diagnosis. In: Detterbeck FC, Rivera MP, Socinski MA, et al, eds. *Diagnosis and treatment of lung cancer: an evidence-based guide for the practicing clinician*. Philadelphia, PA: W. B. Saunders, 2001; 45–72

Seeking a Home for a PET, Part 1: Defining the Appropriate Place for Positron Emission Tomography Imaging in the Diagnosis of Pulmonary Nodules or Masses

Frank C. Detterbeck, Steven Falen, M. Patricia Rivera, Jan S. Halle and Mark A. Socinski

Chest 2004;125:2294-2299
DOI: 10.1378/chest.125.6.2294

This information is current as of February 6, 2007

Updated Information & Services	Updated information and services, including high-resolution figures, can be found at: http://www.chestjournal.org/cgi/content/full/125/6/2294
References	This article cites 26 articles, 22 of which you can access for free at: http://www.chestjournal.org/cgi/content/full/125/6/2294#BIBL
Citations	This article has been cited by 5 HighWire-hosted articles: http://www.chestjournal.org/cgi/content/full/125/6/2294#otherarticles
Permissions & Licensing	Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: http://www.chestjournal.org/misc/reprints.shtml
Reprints	Information about ordering reprints can be found online: http://www.chestjournal.org/misc/reprints.shtml
Email alerting service	Receive free email alerts when new articles cite this article sign up in the box at the top right corner of the online article.
Images in PowerPoint format	Figures that appear in CHEST articles can be downloaded for teaching purposes in PowerPoint slide format. See any online article figure for directions.

