American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Radiologic Management of Thoracic Nodules and Masses**

Variant 1: **Middle-aged patient (35–60 years old) with an incidental 1.5-cm lung nodule. The lesion was smooth. No associated adenopathy. No known risk factors for lung cancer.**

Treatment/Procedure	Rating	Comments
Percutaneous lung biopsy	7	If the patient has significant risk factors, biopsy would be even more indicated.
FDG-PET/CT whole body	7	
Follow-up imaging only	6	The size of the nodule is disconcerting, regardless of the other characteristics.
Surgical lung biopsy/resection	3	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Variant 2: **Middle-aged patient (35–60 years old) who had a CT pulmonary angiogram that was negative for pulmonary embolism but that demonstrated an incidental 1.5-cm lung nodule. The lesion was smooth. No associated adenopathy. Patient has a 70 pack/year smoking history and evidence of significant COPD on chest CT.**

Treatment/Procedure	Rating	Comments
Percutaneous lung biopsy	8	
FDG-PET/CT whole body	8	
Surgical lung biopsy/resection	5	
Follow-up imaging only	2	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Variant 3: **Middle-aged patient (35–60 years old) with a newly diagnosed colon carcinoma. Three pulmonary nodules, ranging up to 2 cm in diameter, noted on staging CT of the chest. At least 1 of the lesions demonstrates a lobulated appearance.**

Treatment/Procedure	Rating	Comments
Percutaneous lung biopsy	8	
FDG-PET/CT whole body	8	
Surgical lung biopsy/resection	3	This procedure is typically reserved for patients in whom percutaneous biopsy cannot be performed or in patients with a negative percutaneous biopsy.
Follow-up imaging only	3	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Clinical Condition: **Radiologic Management of Thoracic Nodules and Masses**

Variant 4: **Young adult patient (20–35 years old) with 1.0-cm smooth-walled noncalcified lung nodule seen on CT after minor motor vehicle trauma. No known risk factors for lung cancer.**

Treatment/Procedure	Rating	Comments
Follow-up imaging only	8	
Percutaneous lung biopsy	3	
FDG-PET/CT whole body	3	
Surgical lung biopsy/resection	2	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Variant 5: **Middle-aged patient (35–60 years old) with persistent 1.5-cm ground-glass nodule noted on an initial CT scan and a follow-up 3-month CT scan. No smoking history and no recent respiratory infection.**

Treatment/Procedure	Rating	Comments
Percutaneous lung biopsy	7	
Surgical lung biopsy/resection	6	Biopsy depends on local percutaneous expertise. Surgical resection can be performed following percutaneous biopsy.
FDG-PET/CT whole body	5	Brochoalveolar carcinoma is often PET negative.
Follow-up imaging only	5	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Variant 6: **Elderly patient (>80 years old) with multifocal <2cm pure ground-glass opacities (no solid component) after chest CT recommended from an abnormal coronary CT examination. No smoking history and no recent respiratory infection.**

Treatment/Procedure	Rating	Comments
Follow-up imaging only	7	Ground-glass nodules typically have a slow growth rate, and a short interim follow-up study may show nodule resolution.
Percutaneous lung biopsy	4	This procedure is performed depending on the clinical functional status of the patient. This procedure may be acceptable, but generally imaging is done first. This procedure is reserved for persistent or growing ground-glass nodules.
Conservative management (do nothing)	4	Conservative management can be used if the patient will not have therapy. All of these can change over time with more data determining the efficacy of tumor-directed therapy (ie, epidermal growth factor receptor inhibitors).
FDG-PET/CT whole body	3	FDG does not significantly accumulate in brochoalveolar carcinoma, well-differentiated adenocarcinomas, and carcinoid tumors.
Surgical lung biopsy/resection	2	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Clinical Condition: **Radiologic Management of Thoracic Nodules and Masses**

Variant 7: **Middle-aged patient (35–60 years old) with a 2-cm smooth-walled lung nodule containing fatty elements by Hounsfield attenuation noted on CT. No prior imaging or risk factors for lung cancer.**

Treatment/Procedure	Rating	Comments
Follow-up imaging only	6	Radiography or CT may be appropriate. For a likely hamartoma, confirm with repeat imaging. This procedure is recommended with a very low probability of cancer by pulmonary nodule calculators.
Conservative management (do nothing)	6	The patient should probably have at least 1 follow-up imaging study.
Percutaneous lung biopsy	2	Hamartomas do not usually require biopsy.
Surgical lung biopsy/resection	2	
FDG-PET/CT whole body	2	No additional imaging is needed. CT is diagnostic.
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Clinical Condition: **Radiologic Management of Thoracic Nodules and Masses**

Variant 8: **Middle-aged patient (35–60 years old) with known multiple pulmonary nodules from metastatic cancer. All lesions but 1 have regressed on the current chemotherapy regimen.**

Treatment/Procedure	Rating	Comments
Percutaneous lung biopsy	7	Sampling is important for mutational testing versus second primary. This procedure is particularly important if results will change therapy. This depends on the location of the lesion and its accessibility by percutaneous techniques. Sampling of nonresponding nodule is useful for mutational genetic testing.
Bronchoscopic biopsy (repeat biopsy)	6	Sampling is important for mutational testing versus second primary. This procedure is recommended only if lesion is adjacent to airway. Traditional transbronchial biopsy historically has a very low yield, but image-guided TBNA will have much better results (ie, EBUS). This procedure is recommended if lesion is amenable to traditional or navigational bronchoscopic biopsy.
FDG-PET/CT whole body	6	This procedure may be appropriate to exclude disease elsewhere. This procedure is unlikely to change management. PET/CT is not helpful in differentiating between primary lung cancer and metastases. FDG-PET may be helpful in identifying nonpulmonary occult metastatic disease.
Surgical lung biopsy/resection	5	Sampling is important for mutational testing versus second primary. This procedure is recommended if lesion is inaccessible by percutaneous or bronchoscopic biopsy. Surgical biopsy may be important if there is uncertainty regarding the diagnosis of the lung lesions, if more tissue is needed to perform molecular testing, or if the patient is a candidate for curative resection, depending on the number of lesions.
Follow-up imaging only	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.
Conservative management (do nothing)	2	
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**		

Clinical Condition: **Radiologic Management of Thoracic Nodules and Masses**

Variant 9: **Elderly patient (>60 years old) with a positive purified protein derivative (tuberculin) test and abnormal chest radiograph. On CT scanning, bulky (up to 3 cm) mediastinal adenopathy is noted throughout the mediastinum (pretracheal, subcarinal, aortopulmonary window). The nodes do not demonstrate calcifications or necrosis. No associated pulmonary nodules.**

Treatment/Procedure	Rating	Comments
Endoscopic/bronchoscopic biopsy	8	
Percutaneous mediastinal biopsy	5	Consider this procedure if bronchoscopic biopsy fails and the mediastinal biopsy can be safely performed percutaneously.
Surgical mediastinal biopsy/resection	4	This procedure might be appropriate, depending on local percutaneous/bronchoscopic biopsy expertise and accessibility of the nodes by nonsurgical approaches.
Follow-up imaging only	2	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Variant 10: **Elderly patient (>60 years old) with a long >30 pack/year smoking history meeting criteria for low-dose screening CT (LDCT). LDCT demonstrates a 2-cm pulmonary nodule in the lingula. There is mediastinal adenopathy (up to 2 cm) in the pretracheal and subcarinal regions as well as left perihilar (up to 2 cm) adenopathy.**

Treatment/Procedure	Rating	Comments
Endoscopic/bronchoscopic mediastinal biopsy	8	This procedure depends on local expertise.
FDG-PET/CT whole body	8	
Percutaneous lung biopsy	7	
Percutaneous mediastinal biopsy	6	This procedure depends on local expertise and accessibility of the nodes by a percutaneous approach.
Surgical pulmonary nodule biopsy/resection	3	
Follow-up imaging only	2	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Clinical Condition: **Radiologic Management of Thoracic Nodules and Masses**

Variant 11: **Middle-aged patient (35–60 years old) with shortness of breath presenting with bilateral hilar adenopathy measuring up to 2 cm, enlarging on serial 3-month imaging. Recent nondiagnostic bronchoscopic biopsy via TBNA. No intraparenchymal pulmonary nodules.**

Treatment/Procedure	Rating	Comments
Bronchoscopic biopsy (repeat biopsy)	7	TBNA is operator dependent. Usually yield is increased with EBUS guidance. This procedure is recommended unless bronchoscopists think there is a reason the first biopsy was inadequate. This depends on the original bronchoscopic technique. Traditional transbronchial biopsy historically has a very low yield, but image-guided TBNA will have much better results (ie, EBUS).
Follow-up imaging only	5	This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.
FDG-PET/CT whole body	5	This procedure is mostly used for staging once the diagnosis is made or if there is a concern for systemic malignancy (extrathoracic neoplasm or lymphoma). This procedure is useful for staging of presumed malignancy.
Surgical lung biopsy/resection	4	This procedure is reserved for nondiagnostic bronchoscopic and percutaneous sampling.
Percutaneous lymph node biopsy	3	This procedure depends on anatomic location. This is almost never necessary for true hilar lymphadenopathy. This procedure is associated with increased pneumothorax risk for hilar biopsies.
Conservative management (do nothing)	2	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

Variant 12: **Middle-aged patient (35–60 years old) presenting with a 3-cm lobular mass involving the left pleura associated with rib erosion.**

Treatment/Procedure	Rating	Comments
Percutaneous lung biopsy	8	
FDG-PET/CT whole body	8	
Surgical pleural biopsy/resection	5	This procedure depends on accessibility by percutaneous approach. Surgical biopsy may be appropriate; however, resection is not likely possible.
Follow-up imaging only	1	
Conservative management (do nothing)	1	
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate		

RADIOLOGIC MANAGEMENT OF THORACIC NODULES AND MASSES

Expert Panel on Interventional Radiology: Benjamin S. English, MD[1]; Charles E. Ray, Jr, MD, PhD[2]; Joe Yujiao Chang, MD, PhD[3]; Traves D. Crabtree, MD[4]; Ron C. Gaba, MD[5]; Matthew G. Gipson, MD[6]; Mark D. Iannettoni, MD[7]; Brian E. Kouri, MD[8]; Francis E. Marshalleck, MBBS[9]; Tan-Lucien H. Mohammed, MD[10]; Jason W. Pinchot, MD[11]; Anthony G. Saleh, MD[12]; Henning Willers, MD[13]; Eric J. Hohenwalter, MD.[14]

Summary of Literature Review

Introduction/Background

Lung cancer causes more deaths than the next 3 most common cancers combined (colon, breast, and prostate). An estimated 162,460 deaths from lung cancer occur in the United States each year, and the incidence of the disease is rising [1]. The diagnosis of lung cancer carries a very poor prognosis; the expected 5-year survival rate for all patients in whom lung cancer is diagnosed is 15.5% (compared to 64.8% for colon cancer, 89% for breast cancer, and 99.9% for prostate cancer). Early diagnosis is vital and significantly improves survival rates. The 5-year survival rate approaches 50% in patients in whom the disease is detected when still localized [2] and 70% for stage IA lung cancer. However, only about 1 in 4 lung cancer cases is diagnosed at an early stage [2].

Metastatic disease to the lungs can occur with virtually any primary malignancy. Diagnosis of such metastases allows for appropriate treatment and prognostication of patients with the disease. Although diffuse metastatic disease to the lungs typically mandates systemic treatment such as intravenous chemotherapy, some primary tumors such as sarcomas may metastasize solely to the lungs, and surgical resection may be curative [3].

Cases in which lung cancer is diagnosed at an early stage are typically asymptomatic, further delaying diagnosis. Solitary pulmonary nodules represent the most typical radiographic presentation of early lung cancer, and multiple pulmonary nodules may be the first sign of malignancy in a patient without a prior diagnosis. Biopsy of pulmonary nodules therefore allows for a tissue diagnosis of malignancy and, in some cases, staging of the primary tumor. Diagnosis by less invasive means may also preclude more invasive surgical procedures performed for diagnosis; this is particularly important in this high-risk patient population. For example, findings from positron emission tomography/computed tomography (PET/CT) have been shown to reduce the number of futile thoracotomies and the total number of thoracotomies [4].

Two recent studies have demonstrated the importance of radiologic imaging and lung cancer screening. The National Lung Cancer Screening Trial assessed whether lung cancer–related mortality could be decreased by having high-risk patients undergo 3 annual screenings with low-dose helical CT [5]. Results from this study demonstrated that, when compared to chest radiography, screening with low-dose CT resulted in a decrease in the number of advanced-stage lung cancers while concurrently resulting in an increase in the number of early lung cancers. There was a 20% reduction in lung cancer mortality from the low-dose CT screening arm compared to chest radiography screening, and there was a 7% reduction in all-cause mortality. The second study evaluated the likelihood of malignancy based on predictive values of specific patient and nodule characteristics noted on screening low-dose CT [6]. Results from this study demonstrated multiple patient and nodule characteristics that significantly increased the likelihood of malignancy, even for very small (<10 mm) pulmonary nodules.

Although these studies and others have demonstrated the ability of low-dose CT to identify early-stage malignancy in high-risk patients, concern has been raised about both the radiation exposure to the public with aggressive and widespread screening protocols as well as the low yield of screening protocols. In 1 large study from Italy (ITALUNG), a yield of only 2.0% for malignancy was noted in patients exposed to up to 4 annual screening CT scans [7].

[1]Research Author, University of Colorado Denver and Health Sciences Center, Aurora, Colorado. [2]Principal Author and Specialty Chair, University of Illinois Hospital and Health Science System, Chicago, Illinois. [3]University of Texas MD Anderson Cancer Center, Houston, Texas. [4]Washington University School of Medicine, Saint Louis, Missouri, Society of Thoracic Surgeons. [5]University of Illinois Hospital, Chicago, Illinois. [6]University of Colorado, Anschutz Medical Campus, Aurora, Colorado. [7]University of Iowa, Iowa City, Iowa, Society of Thoracic Surgeons. [8]Wake Forest University Baptist Medical Center, Winston-Salem, North Carolina. [9]Riley Hospital for Children, Indianapolis, Indiana. [10]University of Florida College of Medicine, Gainesville, Florida. [11]University of Wisconsin, Madison, Wisconsin. [12]New York Methodist Hospital, Brooklyn, New York, the American College of Chest Physicians. [13]Massachusetts General Hospital, Boston, Massachusetts. [14]Panel Chair, Froedtert & the Medical College of Wisconsin, Milwaukee, Wisconsin.

It is important to note the demographic referenced as high risk for lung cancer. The Center for Medicare and Medicaid Services currently defines this high-risk population as individuals 55–74 years of age with a smoking history of at least 30 years who are either current smokers or have quit within the last 15 years.

Due to the nature of this document, its discussion of biopsies centers on percutaneous approaches. Since percutaneous biopsies are now typically considered a first-line procedure, there is a severe paucity of recent literature directly comparing percutaneous to other approaches (eg, surgical, video-assisted thoracoscopy, or bronchoscopy with or without fluoroscopic or endobronchial/endoscopic ultrasound [EBUS] guidance). The reader should keep these other approaches in mind and on a case-by-case basis based on anatomy and clinical presentation should determine whether or not nonpercutaneous approaches should be seriously considered.

Discussion by Variant

Variants 1 through 8: Pulmonary nodules

Most biopsies in the thorax will be performed for pulmonary nodules. These nodules may be solitary or multiple; in the latter case, metastatic disease or an infectious etiology is more likely than a primary lung cancer. Initial clinical evaluation, including known risk factors for lung cancer, is necessary before biopsy is attempted. There are several published guidelines for the management of small pulmonary nodules detected on CT scans, the most widely cited of which is supported by the Fleischner Society [8]. A new reporting and management lexicon developed in 2014 by the American College of Radiology serves as a quality assurance tool designed to standardize lung cancer CT screening reporting and management recommendations. This lung nodule management tool is referenced on the ACR website: http://www.acr.org/Quality-Safety/Resources/LungRADS.

Many nonradiologists use "pulmonary nodule calculators" to estimate the pretest probability of malignancy for any given solitary pulmonary nodule. By inputting several clinical and radiologic risk factors that increase the likelihood of malignancy (eg, age, smoking history, and size and morphology of the nodule), a calculation is performed that gives the probability of malignancy for a patient presenting with a solitary pulmonary nodule. The American College of Chest Physicians recommends the use of pulmonary nodule calculators when determining the diagnostic and/or treatment algorithm to be undertaken for patients presenting with solitary pulmonary nodules. These calculators are widely available on the Internet.

There is a distinct paucity of evidence in the literature directly comparing biopsy techniques across multiple specialties. Methods by which biopsies may be obtained include percutaneous biopsy with imaging guidance, mediastinoscopy with biopsy, bronchoscopy-guided transbronchial biopsy, video-assisted thoracoscopy, endoscopic US transesophageal biopsy, or open surgical biopsy. The location of the nodule (eg, subpleural, paramediastinal, subcarinal, endobronchial) significantly affects the likelihood of success of 1 form of biopsy compared to another. Recent evidence suggests that adjustment of intraprocedural CT scanning techniques can significantly decrease the amount of radiation exposure during biopsies [9].

Patients in whom biopsies are performed are often considered to be at high risk for complications from the procedure. These risks (eg, pneumothorax, bleeding, and bronchopleural fistula) are largely due to the poor underlying pulmonary reserve and high incidence of chronic obstructive pulmonary disease (COPD) in this patient population. Patients should be counseled before the procedure regarding the significant risks associated with their biopsy.

In addition to problems associated with a relatively high-risk patient population, percutaneous biopsies of pulmonary nodules may be difficult to perform technically. Patients may often have difficulty suspending respirations or may take variable volume breaths, resulting in the target lesion moving in and out of the biopsy plane. Lesions may also be very small or central (deep) in location, making needle placement challenging. For these reasons and others, the failure rate of lung biopsies is relatively high. The Society of Interventional Radiology guidelines for lung biopsy specify that an 85% success rate is acceptable [10].

Characteristics of pulmonary nodules affect the likelihood of malignancy. Morphologic characteristics such as smooth and well-defined margins and diffuse or central nodular calcifications favor benign etiology. Although persistent ground-glass and mixed ground-glass density nodules have traditionally been thought to have a high rate of malignancy [11-15], recent evidence suggests that the slow progression of such nodules may indicate that active surveillance can be a reasonable approach to this patient population [16]. The likelihood of cancer diagnosis increases with the size of the pulmonary nodule, regardless of solid or ground-glass density. Nodules >3 cm in diameter are considered pulmonary malignancies until proven otherwise. Other characteristics, such as

growth rate, dynamic changes on contrast-enhanced helical CT, and uptake of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG) during PET imaging, may help in distinguishing benign from malignant lesions [17].

A recent report demonstrates that the diameter of solid tumor size and maximum activity on PET demonstrate a greater predictive value for high-grade malignancies than the normally measured whole tumor size [18]. Although the demonstration of certain characteristics with cross-sectional imaging has improved the likelihood of malignancy, CT has still not replaced biopsy as the definitive examination of choice. One recent study directly comparing CT findings with biopsy results (in 129 patients already considered to be high risk for malignancy, given their imaging findings) demonstrated a CT sensitivity of 95% and positive predictive value of 83% but also reported only 43% specificity and a 75% negative predictive value [19].

FDG is accumulated in malignant nodules. Benign lesions such as hamartomas and inflammatory nodules do not significantly accumulate FDG. Thus, PET is a valuable tool in evaluation of indeterminate lesions. In 1 meta-analysis of 1474 pulmonary nodules [20], PET was 97% sensitive and 78% specific. It is important to recognize the limitations of PET. It is best used in patients with nodules >0.8 mm in diameter, as smaller nodules may result in a false-negative study [21]. False-negative scans may also occur in cancer presenting as a predominant ground-glass opacity and with malignancies such as well-differentiated adenocarcinomas, brochoalveolar cell carcinomas, and carcinoid tumors [22]. False-positive lesions may result in patients with tuberculosis, fungal infections, or sarcoidosis [23]. Although helpful in determining the FDG uptake and metabolic activity in pulmonary nodules, PET remains relatively inaccurate (particularly with regards to specificity) and therefore has limited use in the initial diagnosis of pulmonary malignancy [24,25]. Once a tissue diagnosis is made, PET is the standard for initial staging before treatment and may prove to have a significant role in pulmonary nodules post-treatment [26].

Transthoracic needle aspiration and biopsy are the mainstays for obtaining tissue for histopathologic diagnosis of pulmonary nodules, and they usually provide adequate tissue quantity for biochemical analysis [27]. Endoscopic US-guided procedures allow only fine-needle aspiration (FNA) of individual cells, usually sufficient for staging purposes [28]. However, recent advances in targeted cancer pharmacotherapy based on genetics of specific tumors may require a greater quantity of tissue and require more core biopsy specimens [29]**.** Several technical measures may increase the yield or decrease the risk of percutaneous biopsies:

1. Preselecting patients with nodules having high potential for malignancy.
2. Providing on-site analysis of the specimen, rather than placing the specimen in fixative for later analysis, allows for higher diagnostic accuracy [20,30-32].
3. Performing both FNA and core biopsies of the same lesion has been shown to increase yield over FNA alone [33], particularly in the diagnosis of benign nodules.
4. Using a steeper angle of the biopsy needle and placing the patient prone may decrease the risk of pneumothorax [34,35].
5. Using a 19-gauge or smaller needle [36].

Percutaneous biopsy is limited in its ability to obtain a specific diagnosis of a benign pulmonary process, and yields of ≤50% are expected [37]. Performing both core biopsies and FNA of benign lesions significantly increases the diagnostic yield [38]. In addition, some investigators have suggested that multiple larger biopsies (at least three ≥1 cm in length) increase the yield of diagnosis for benign lesions [39].

In certain instances, nonradiologic biopsies of pulmonary nodules may provide higher yields than image-guided procedures. Video-assisted thoracoscopic biopsy may have a very high success rate in patients with subpleural nodules, and bronchoscopic biopsy of central intraluminal lesions may also provide better success rates compared to percutaneous biopsy. Although the data are currently sparse, performing molecular analysis on bronchoscopically obtained endobronchial epithelial lining fluid from a subsegmental bronchus close to a pulmonary nodule has shown promise in the early diagnosis of lung cancer [40]. At this time, for peripheral pulmonary nodules, CT-guided biopsies still provide a higher yield than endobronchial US-guided sheath biopsies [41].

Percutaneous lung biopsy is generally associated with higher complication rates compared to solid organ biopsy. The Society of Interventional Radiology has published guidelines stating that an overall complication rate of 10% is acceptable for lung biopsies, compared to 2% for all other organ systems [10]. The most common complication of percutaneous lung biopsy is bleeding (hemoptysis, chest wall, parenchymal); however, the most common complication requiring intervention is pneumothorax (10%–30%). Chest tube insertion is needed in approximately

one-third of patients with pneumothoraces. Most postbiopsy complications can be treated conservatively, often on an outpatient basis [42-44]. Some evidence suggests that the use of an autologous intraparenchymal blood patch decreases the rate of pneumothorax requiring chest tube insertion [45,46]. Embolization of the tract following biopsy using a coaxial system has been described, with embolization agents varying from collagen foam plugs to autologous clot to fibrin glue to normal saline [45-49]. The risk of chest wall implantation caused by percutaneous biopsy is rare, with reports ranging from 0% to 3% [50,51].

Patients who undergo percutaneous lung biopsies that yield a definitive malignant diagnosis may or may not undergo therapy. False-positive results are very rare. Patients with definitive benign diagnoses can be managed conservatively, although false-negative results may occur in a minority of patients. Patients who do not have either a definitive malignant or benign diagnosis need close follow-up, surgical referral, or repeat biopsy (either percutaneous or by other means). Death from percutaneous lung biopsy is extremely rare but may occur from systemic air embolism.

Variants 9 through 11: Mediastinal nodes and masses

Mediastinal masses may arise without a concurrent intraparenchymal pulmonary mass and may represent metastatic disease. Definitive diagnosis by biopsy is vital in that it may significantly change the treatment options or may preclude the need for exploratory surgery. The best method of biopsy largely depends on the location of the mass and the proximity of adjacent structures.

Image-guided biopsies of mediastinal masses are almost always performed using CT guidance. The lack of an acoustic window prevents the use of US, unless the mass extends to the pleural surface or invades the chest wall. Real-time CT guidance, however, may be more difficult than expected because of its relatively poor visualization of vascular structures on unenhanced CT. In select instances, the use of iatrogenic saline windows (so-called "salinomas") or artificially-induced pneumothoraces may be helpful in decreasing the incidence of postbiopsy pneumothorax by moving the pleural surface away from the needle path [52,53]. Several approaches have been described, including parasternal, suprasternal, and even trans-sternal. Awareness of the internal mammary vessels is crucial in safely performing a parasternal approach. Although MRI-guided percutaneous biopsy of mediastinal masses has been proven to be safe and effective, current technology limits its widespread use [54].

Traditionally, central pulmonary hilar lesions are approached by bronchoscopic biopsy with or without endobronchial US guidance. However, CT-guided biopsy of pulmonary hilar lesions has high sensitivity and accuracy and is a viable alternative for bronchoscopic biopsy, though the procedure can result in high rates of pneumothorax and chest tube insertion [28].

Nonradiologic mediastinal mass biopsy may be safer and have higher yields than radiologic biopsy. Bronchoscopically guided transbronchial FNA [55], endoscopic transesophageal US with FNA [56-59], mediastinoscopy [57], endobronchial US [60,61], and thoracoscopy [62] can all be used to obtain tissue from mediastinal masses. One recent study suggested that endobronchial US-guided transbronchial needle aspiration (TBNA) was preferable as the primary procedure to endoscopic US-guided FNA in the mediastinal staging of lung cancer, although many patients required both examinations to make the definitive diagnosis [63]. The indications for image-guided versus nonradiologic procedures will vary from institution to institution.

Variant 12: Pleural biopsies

Although malignant processes affecting the pleural surface can sometimes be diagnosed by evaluating pleural fluid on the affected side, the yield of such a procedure is often low. Pleural biopsies can be separated on the basis of whether the region of interest is a focal mass or a diffuse process. Biopsies for diffuse processes, such as tuberculosis, are frequently done without imaging guidance. Biopsies for focal pleural-based mass lesions can frequently be performed with US guidance, particularly in the presence of a pleural effusion; diagnostic yield is essentially the same with US as with CT guidance [64]. Due to the paucity of evidence in the literature, complication rates of pleural mass–based biopsies are impossible to determine; however, it is anticipated that the risk of pneumothorax will be somewhat lower than that demonstrated with intraparenchymal biopsies.

Summary of Recommendations

Intraparenchymal pulmonary nodules:

- The choice of modalities (percutaneous with imaging guidance, bronchoscopy, video-assisted thoracoscopy, mediastinoscopy, or open surgical) depends in large part on the location and size of the lesion, the underlying pulmonary function, adjacent structures, clinical expertise at the particular practice, and operator preference.

- In patients with incidentally noted pulmonary nodules that do NOT have an appearance typical of malignancy (eg, nodule has smooth borders and calcification and does not invade surrounding structures) and no known risk factors, conservative follow-up with imaging is more appropriate than biopsy.
- PET imaging is very sensitive for nodules >0.8 mm in diameter; however, there is a relatively high rate of false negatives. PET may be particularly helpful during follow-up of patients postintervention and for assessing patients for distant metastatic disease.
- Increased diagnostic yield is expected when core biopsy is performed in addition to FNA. The greater tissue yield also allows for mutational tumor-specific genetic testing.
- Slide fixation at the time of FNA improves diagnostic yield compared to placing the specimen in a fixative for later cytopathologic evaluation.
- Most complications can be treated using percutaneous techniques, and many can be treated on an outpatient basis.
- Delayed pneumothorax is known to occur but is a rare complication.

Mediastinal masses/adenopathy:

- In select patient populations, image-guided percutaneous FNA and biopsy may provide the highest diagnostic yield in the safest manner.
- Nonradiologic biopsies (eg, mediastinoscopy with biopsy, bronchoscopic or endoscopic US-guided transbronchial or transesophageal biopsy) may provide a safer alternative to percutaneous biopsy.

Pleural biopsies:

- Pleural biopsies for diffuse disease (eg, tuberculosis) can typically be performed without imaging guidance.
- Biopsies of focal pleural masses can be performed safely with either CT or US guidance.

Many of the diagnostic, surgical, and interventional procedures described here are highly specialized. Their availability and utility vary by institutional and operator experience.

Summary of Evidence

Of the *64* references cited in the *ACR Appropriateness Criteria® Radiologic Management of Thoracic Nodules and Masses* document, 60 are categorized as diagnostic references including 5 well designed studies, 7 good quality studies, and 27 quality studies that may have design limitations. Additionally, 4 references are categorized as therapeutic references including 1 good quality study. There are 24 references that may not be useful as primary evidence.

The 64 references cited in the *ACR Appropriateness Criteria® Radiologic Management of Thoracic Nodules and Masses* document were published from 1995-2014.

While there are references that report on studies with design limitations, 13 well designed or good quality studies provide good evidence.

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

1. Siegel R, Ma J, Zou Z, Jemal A. Cancer statistics, 2014. *CA Cancer J Clin.* 2014;64(1):9-29.
2. Howlader N, Noone AM, Krapcho M, et al. SEER Cancer Statistics Review, 1975-2011, National Cancer Institute. Bethesda, MD, http://seer.cancer.gov/csr/1975_2011/, based on November 2013 SEER data submission, posted to the SEER web site, April 2014. Accessed September 30, 2015.
3. Suzuki M, Iwata T, Ando S, et al. Predictors of long-term survival with pulmonary metastasectomy for osteosarcomas and soft tissue sarcomas. *J Cardiovasc Surg (Torino).* 2006;47(5):603-608.
4. Fischer B, Lassen U, Mortensen J, et al. Preoperative staging of lung cancer with combined PET-CT. *N Engl J Med.* 2009;361(1):32-39.
5. Aberle DR, DeMello S, Berg CD, et al. Results of the two incidence screenings in the National Lung Screening Trial. *N Engl J Med.* 2013;369(10):920-931.

6. McWilliams A, Tammemagi MC, Mayo JR, et al. Probability of cancer in pulmonary nodules detected on first screening CT. *N Engl J Med.* 2013;369(10):910-919.
7. Lopes Pegna A, Picozzi G, Falaschi F, et al. Four-year results of low-dose CT screening and nodule management in the ITALUNG trial. *J Thorac Oncol.* 2013;8(7):866-875.
8. MacMahon H, Austin JH, Gamsu G, et al. Guidelines for management of small pulmonary nodules detected on CT scans: a statement from the Fleischner Society. *Radiology.* 2005;237(2):395-400.
9. Adiga S, Athreya S. Safety, efficacy, and feasibility of an ultra-low dose radiation protocol for CT-guided percutaneous needle biopsy of pulmonary lesions: initial experience. *Clin Radiol.* 2014;69(7):709-714.
10. Cardella JF, Bakal CW, Bertino RE, et al. Quality improvement guidelines for image-guided percutaneous biopsy in adults. *J Vasc Interv Radiol.* 2003;14(9 Pt 2):S227-230.
11. Godoy MC, Naidich DP. Subsolid pulmonary nodules and the spectrum of peripheral adenocarcinomas of the lung: recommended interim guidelines for assessment and management. *Radiology.* 2009;253(3):606-622.
12. Kim HY, Shim YM, Lee KS, Han J, Yi CA, Kim YK. Persistent pulmonary nodular ground-glass opacity at thin-section CT: histopathologic comparisons. *Radiology.* 2007;245(1):267-275.
13. Lee HJ, Goo JM, Lee CH, Yoo CG, Kim YT, Im JG. Nodular ground-glass opacities on thin-section CT: size change during follow-up and pathological results. *Korean J Radiol.* 2007;8(1):22-31.
14. Fan L, Liu SY, Li QC, Yu H, Xiao XS. Multidetector CT features of pulmonary focal ground-glass opacity: differences between benign and malignant. *Br J Radiol.* 2012;85(1015):897-904.
15. Lim HJ, Ahn S, Lee KS, et al. Persistent pure ground-glass opacity lung nodules >/= 10 mm in diameter at CT scan: histopathologic comparisons and prognostic implications. *Chest.* 2013;144(4):1291-1299.
16. Silva M, Sverzellati N, Manna C, et al. Long-term surveillance of ground-glass nodules: evidence from the MILD trial. *J Thorac Oncol.* 2012;7(10):1541-1546.
17. Jeong YJ, Yi CA, Lee KS. Solitary pulmonary nodules: detection, characterization, and guidance for further diagnostic workup and treatment. *AJR Am J Roentgenol.* 2007;188(1):57-68.
18. Tsutani Y, Miyata Y, Nakayama H, et al. Prognostic significance of using solid versus whole tumor size on high-resolution computed tomography for predicting pathologic malignant grade of tumors in clinical stage IA lung adenocarcinoma: a multicenter study. *J Thorac Cardiovasc Surg.* 2012;143(3):607-612.
19. Maataoui A, Vogl TJ, Jacobi V, Khan MF. Diagnostic accuracy of CT readings on coin lesions in the lung as compared with transthoracic CT-guided needle biopsy results. *Pneumologie.* 2012;66(7):432-436.
20. Chandan VS, Zimmerman K, Baker P, Scalzetti E, Khurana KK. Usefulness of core roll preparations in immediate assessment of neoplastic lung lesions: comparison to conventional CT scan-guided lung fine-needle aspiration cytology. *Chest.* 2004;126(3):739-743.
21. Mayerhoefer ME, Prosch H, Herold CJ, Weber M, Karanikas G. Assessment of pulmonary melanoma metastases with 18F-FDG PET/CT: which PET-negative patients require additional tests for definitive staging? *Eur Radiol.* 2012;22(11):2451-2457.
22. Kim TJ, Park CM, Goo JM, Lee KW. Is there a role for FDG PET in the management of lung cancer manifesting predominantly as ground-glass opacity? *AJR Am J Roentgenol.* 2012;198(1):83-88.
23. Chang CY, Tzao C, Lee SC, et al. Incremental value of integrated FDG-PET/CT in evaluating indeterminate solitary pulmonary nodule for malignancy. *Mol Imaging Biol.* 2010;12(2):204-209.
24. Harders SW, Madsen HH, Hjorthaug K, et al. Characterization of pulmonary lesions in patients with suspected lung cancer: computed tomography versus [(1)(8)F] fluorodeoxyglucose-positron emission tomography/computed tomography. *Cancer Imaging.* 2012;12:437-446.
25. Sim YT, Goh YG, Dempsey MF, Han S, Poon FW. PET-CT evaluation of solitary pulmonary nodules: correlation with maximum standardized uptake value and pathology. *Lung.* 2013;191(6):625-632.
26. Takeda A, Kunieda E, Fujii H, et al. Evaluation for local failure by 18F-FDG PET/CT in comparison with CT findings after stereotactic body radiotherapy (SBRT) for localized non-small-cell lung cancer. *Lung Cancer.* 2013;79(3):248-253.
27. Chen CM, Chang JW, Cheung YC, et al. Computed tomography-guided core-needle biopsy specimens demonstrate epidermal growth factor receptor mutations in patients with non-small-cell lung cancer. *Acta Radiol.* 2008;49(9):991-994.
28. Avritscher R, Krishnamurthy S, Ensor J, et al. Accuracy and sensitivity of computed tomography-guided percutaneous needle biopsy of pulmonary hilar lymph nodes. *Cancer.* 2010;116(8):1974-1980.
29. Solomon SB, Zakowski MF, Pao W, et al. Core needle lung biopsy specimens: adequacy for EGFR and KRAS mutational analysis. *AJR Am J Roentgenol.* 2010;194(1):266-269.

30. Diacon AH, Schuurmans MM, Theron J, et al. Transbronchial needle aspirates: comparison of two preparation methods. *Chest.* 2005;127(6):2015-2018.
31. Kucuk CU, Yilmaz A, Akkaya E. Computed tomography-guided transthoracic fine-needle aspiration in diagnosis of lung cancer: a comparison of single-pass needle and multiple-pass coaxial needle systems and the value of immediate cytological assessment. *Respirology.* 2004;9(3):392-396.
32. Mazza E, Maddau C, Ricciardi A, Falchini M, Matucci M, Ciarpallini T. On-site evaluation of percutaneous CT-guided fine needle aspiration of pulmonary lesions. A study of 321 cases. *Radiol Med.* 2005;110(3):141-148.
33. Yamagami T, Iida S, Kato T, Tanaka O, Nishimura T. Combining fine-needle aspiration and core biopsy under CT fluoroscopy guidance: a better way to treat patients with lung nodules? *AJR Am J Roentgenol.* 2003;180(3):811-815.
34. Ko JP, Shepard JO, Drucker EA, et al. Factors influencing pneumothorax rate at lung biopsy: are dwell time and angle of pleural puncture contributing factors? *Radiology.* 2001;218(2):491-496.
35. Nakamura M, Yoshizako T, Koyama S, Kitagaki H. Risk factors influencing chest tube placement among patients with pneumothorax because of CT-guided needle biopsy of the lung. *J Med Imaging Radiat Oncol.* 2011;55(5):474-478.
36. Geraghty PR, Kee ST, McFarlane G, Razavi MK, Sze DY, Dake MD. CT-guided transthoracic needle aspiration biopsy of pulmonary nodules: needle size and pneumothorax rate. *Radiology.* 2003;229(2):475-481.
37. Kothary N, Bartos JA, Hwang GL, Dua R, Kuo WT, Hofmann LV. Computed tomography-guided percutaneous needle biopsy of indeterminate pulmonary pathology: efficacy of obtaining a diagnostic sample in immunocompetent and immunocompromised patients. *Clin Lung Cancer.* 2010;11(4):251-256.
38. Aviram G, Greif J, Man A, et al. Diagnosis of intrathoracic lesions: are sequential fine-needle aspiration (FNA) and core needle biopsy (CNB) combined better than either investigation alone? *Clin Radiol.* 2007;62(3):221-226.
39. Doxtader EE, Mukhopadhyay S, Katzenstein AL. Core needle biopsy in benign lung lesions: pathologic findings in 159 cases. *Hum Pathol.* 2010;41(11):1530-1535.
40. Kahn N, Meister M, Eberhardt R, et al. Early detection of lung cancer by molecular markers in endobronchial epithelial-lining fluid. *J Thorac Oncol.* 2012;7(6):1001-1008.
41. Fielding DI, Chia C, Nguyen P, et al. Prospective randomised trial of endobronchial ultrasound-guide sheath versus computed tomography-guided percutaneous core biopsies for peripheral lung lesions. *Intern Med J.* 2012;42(8):894-900.
42. Covey AM, Gandhi R, Brody LA, Getrajdman G, Thaler HT, Brown KT. Factors associated with pneumothorax and pneumothorax requiring treatment after percutaneous lung biopsy in 443 consecutive patients. *J Vasc Interv Radiol.* 2004;15(5):479-483.
43. Hiraki T, Mimura H, Gobara H, et al. Incidence of and risk factors for pneumothorax and chest tube placement after CT fluoroscopy-guided percutaneous lung biopsy: retrospective analysis of the procedures conducted over a 9-year period. *AJR Am J Roentgenol.* 2010;194(3):809-814.
44. Yaffe D, Shitrit D, Gottfried M, Bartal G, Sosna J. Ipsilateral opposite-side aspiration in resistant pneumothorax after CT image guided lung biopsy: complementary role after simple needle aspiration. *Chest.* 2013;144(3):947-951.
45. Malone LJ, Stanfill RM, Wang H, Fahey KM, Bertino RE. Effect of intraparenchymal blood patch on rates of pneumothorax and pneumothorax requiring chest tube placement after percutaneous lung biopsy. *AJR Am J Roentgenol.* 2013;200(6):1238-1243.
46. Wagner JM, Hinshaw JL, Lubner MG, et al. CT-guided lung biopsies: pleural blood patching reduces the rate of chest tube placement for postbiopsy pneumothorax. *AJR Am J Roentgenol.* 2011;197(4):783-788.
47. Tran AA, Brown SB, Rosenberg J, Hovsepian DM. Tract embolization with gelatin sponge slurry for prevention of pneumothorax after percutaneous computed tomography-guided lung biopsy. *Cardiovasc Intervent Radiol.* 2014;37(6):1546-1553.
48. Petsas T, Siamblis D, Giannakenas C, et al. Fibrin glue for sealing the needle track in fine-needle percutaneous lung biopsy using a coaxial system: Part II--Clinical study. *Cardiovasc Intervent Radiol.* 1995;18(6):378-382.
49. Billich C, Muche R, Brenner G, et al. CT-guided lung biopsy: incidence of pneumothorax after instillation of NaCl into the biopsy track. *Eur Radiol.* 2008;18(6):1146-1152.

50. Matsuguma H, Nakahara R, Kondo T, Kamiyama Y, Mori K, Yokoi K. Risk of pleural recurrence after needle biopsy in patients with resected early stage lung cancer. *Ann Thorac Surg.* 2005;80(6):2026-2031.
51. Sano Y, Date H, Toyooka S, et al. Percutaneous computed tomography-guided lung biopsy and pleural dissemination: an assessment by intraoperative pleural lavage cytology. *Cancer.* 2009;115(23):5526-5533.
52. Zwischenberger JB, Savage C, Alpard SK, Anderson CM, Marroquin S, Goodacre BW. Mediastinal transthoracic needle and core lymph node biopsy: should it replace mediastinoscopy? *Chest.* 2002;121(4):1165-1170.
53. Lin ZY, Li YG. Artificial pneumothorax with position adjustment for computed tomography-guided percutaneous core biopsy of mediastinum lesions. *Ann Thorac Surg.* 2009;87(3):920-924.
54. Lu Y, Fritz J, Li C, et al. Magnetic resonance imaging-guided percutaneous biopsy of mediastinal masses: diagnostic performance and safety. *Invest Radiol.* 2013;48(6):452-457.
55. Shah PL, Singh S, Bower M, Livni N, Padley S, Nicholson AG. The role of transbronchial fine needle aspiration in an integrated care pathway for the assessment of patients with suspected lung cancer. *J Thorac Oncol.* 2006;1(4):324-327.
56. Annema JT, Versteegh MI, Veselic M, Voigt P, Rabe KF. Endoscopic ultrasound-guided fine-needle aspiration in the diagnosis and staging of lung cancer and its impact on surgical staging. *J Clin Oncol.* 2005;23(33):8357-8361.
57. Cerfolio RJ, Bryant AS, Eloubeidi MA. Routine mediastinoscopy and esophageal ultrasound fine-needle aspiration in patients with non-small cell lung cancer who are clinically N2 negative: a prospective study. *Chest.* 2006;130(6):1791-1795.
58. Herth FJ, Ernst A, Eberhardt R, Vilmann P, Dienemann H, Krasnik M. Endobronchial ultrasound-guided transbronchial needle aspiration of lymph nodes in the radiologically normal mediastinum. *Eur Respir J.* 2006;28(5):910-914.
59. Singh P, Camazine B, Jadhav Y, et al. Endoscopic ultrasound as a first test for diagnosis and staging of lung cancer: a prospective study. *Am J Respir Crit Care Med.* 2007;175(4):345-354.
60. Herth FJ, Becker HD, Ernst A. Ultrasound-guided transbronchial needle aspiration: an experience in 242 patients. *Chest.* 2003;123(2):604-607.
61. Navani N, Lawrence DR, Kolvekar S, et al. Endobronchial ultrasound-guided transbronchial needle aspiration prevents mediastinoscopies in the diagnosis of isolated mediastinal lymphadenopathy: a prospective trial. *Am J Respir Crit Care Med.* 2012;186(3):255-260.
62. Minnich DJ, Bryant AS, Cerfolio RJ. Thoracoscopic and robotic dissection of mediastinal lymph nodes. *Thorac Surg Clin.* 2012;22(2):215-218.
63. Kang HJ, Hwangbo B, Lee GK, et al. EBUS-centred versus EUS-centred mediastinal staging in lung cancer: a randomised controlled trial. *Thorax.* 2014;69(3):261-268.
64. Sconfienza LM, Mauri G, Grossi F, et al. Pleural and peripheral lung lesions: comparison of US- and CT-guided biopsy. *Radiology.* 2013;266(3):930-935.