American College of Radiology
ACR Appropriateness Criteria®
Occupational Lung Diseases

Variant 1: **Occupational exposure, screening, and surveillance of lung disease. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	☢
CT chest without IV contrast	May Be Appropriate	☢☢☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
MRI chest without and with IV contrast	Usually Not Appropriate	O
MRI chest without IV contrast	Usually Not Appropriate	O

Variant 2: **Occupational exposure, suspected interstitial lung disease. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT chest without IV contrast	Usually Appropriate	☢☢☢
Radiography chest	Usually Appropriate	☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
MRI chest without and with IV contrast	Usually Not Appropriate	O
MRI chest without IV contrast	Usually Not Appropriate	O
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant 3: **Occupational exposure, suspected interstitial lung disease based on radiography. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
CT chest without IV contrast	Usually Appropriate	☢☢☢
MRI chest without and with IV contrast	Usually Not Appropriate	O
MRI chest without IV contrast	Usually Not Appropriate	O
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
Image-guided transthoracic needle biopsy	Usually Not Appropriate	Varies

Variant 4: **Occupational exposure, suspected airway disease. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT chest without IV contrast	Usually Appropriate	☢☢☢
Radiography chest	Usually Appropriate	☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
MRI chest without and with IV contrast	Usually Not Appropriate	O
MRI chest without IV contrast	Usually Not Appropriate	O
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Variant 5: **Confirmed occupational lung disease, suspected thoracic neoplasm.**

Procedure	Appropriateness Category	Relative Radiation Level
CT chest with IV contrast	Usually Appropriate	☢☢☢
Image-guided transthoracic needle biopsy	Usually Appropriate	Varies
CT chest without IV contrast	May Be Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	May Be Appropriate	☢☢☢☢
Radiography chest	May Be Appropriate	☢
MRI chest without and with IV contrast	May Be Appropriate	O
MRI chest without IV contrast	May Be Appropriate	O
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢

OCCUPATIONAL LUNG DISEASES

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Summary of Literature Review

Introduction/Background

Inhalational exposures in the workplace that result in airway, parenchymal, or pleural pathology constitute an "occupational lung disease." Typical occupational exposures include inhalation of inorganic particles such as silica dust, coal dust, and asbestos fibers resulting in pneumoconioses; organic dust inhalation resulting in hypersensitivity pneumonitis; and other various inhalants resulting in airway or lung injury. Updating the definition of occupational lung disease aligns more closely with current definitions by pulmonary, occupational, and environmental medicine societies [1-3].

Despite well-known risks and mitigation efforts, occupational lung diseases such as the pneumoconioses continue to arise for a variety of reasons [4-11]. Medical imaging continues to play a critical role in the diagnosis and management of occupational lung disease, with increasing use of chest CT, particularly at reduced dose [12-14]. Various biomarkers in conjunction with medical imaging are proving to further refine assessment [15-20]. As in other areas of diffuse lung disease, multidisciplinary assessment consistently demonstrates improved characterization of occupational lung disease [21-28].

Special Imaging Considerations

Imaging of emerging occupational lung diseases deserves special consideration. Imaging and pathologic manifestations may not be known in the setting of a new and unique exposure, potentially requiring a broader diagnostic evaluation than the variants discussed below [6,29-38].

Discussion of Procedures by Variant

Variant 1: Occupational exposure, screening, and surveillance of lung disease. Initial imaging.

Radiography Chest

Driven by the International Labor Organization classification scheme for screening and surveillance of pneumoconioses, chest radiography remains an important imaging modality in the arena of occupational lung disease. Epidemiologic studies using radiographs to screen United States coal miners continue to demonstrate developing coal workers pneumoconiosis [9,11,39,40]. Screening and surveillance of various occupations with chest radiographs reveal ongoing and new lung disease risks [7,8,41,42]. Additionally, chest radiographs have demonstrated correlation with physiologic testing [43]. In 2011, the International Labor Organization criteria for radiograph acquisition have expanded to include digital radiography with flat-panel detector viewing [44]. More recent studies continue to support the equivalence of analog radiography and digital radiography [40,45-47].

CT Chest

Although no studies have implemented a population-based CT screening and surveillance program specifically for occupational lung disease to examine morbidity or mortality benefit, several recent studies have used reduced-dose CT to demonstrate adequate detection of parenchymal changes in at-risk workers. In a prospective study of 55 patients with a 15-year asbestos exposure history, screening ultra-low-dose chest CT was compared with standard acquisition chest CT, demonstrating 91% sensitivity and 100% specificity for asbestos-associated primary endpoint findings [12]. Retrospective studies utilizing lung cancer screening examinations have also revealed potential

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benefit. For instance, Carrillo et al [48] found 44% of patients with an asbestos exposure history had associated pulmonary parenchymal abnormalities on low-dose CT performed for lung cancer screening. The International Classification of High-Resolution Computed Tomography for Occupational and Environmental Respiratory Diseases aims to standardize high-resolution CT (HRCT) findings for occupational screening [49]. CT with intravenous (IV) contrast serves no purpose in the setting of occupational lung disease screening and surveillance.

MRI Chest
Though there is evidence that shows that proton MRI may be useful in the setting of interstitial lung disease (ILD) and pulmonary fibrosis [50-53], there is no direct evidence to support the use of MRI as an initial imaging technique in population-based screening and surveillance of occupational lung disease.

FDG-PET/CT Skull Base to Mid-Thigh
There is no relevant literature to support the use of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT as an initial imaging technique in population-based screening and surveillance of occupational lung disease.

Variant 2: Occupational exposure, suspected interstitial lung disease. Initial imaging.

Radiography Chest
The chest radiograph and CT are complementary in the initial workup of suspected occupational lung disease [21,24,54,55]. When patients with occupational exposures present with respiratory symptoms, chest radiography serves as the primary function of excluding alternative diagnoses, such as infectious pneumonia or pulmonary edema, with HRCT findings offering the best characterization of lung disease.

CT Chest
The primary imaging modality for symptomatic occupational lung disease is chest HRCT that often provides a definitive diagnosis, obviating the need for surgical biopsy. Ongoing studies continue to support the increased sensitivity and specificity of HRCT over chest radiography for changes related to occupational lung disease [26,43,56-58], although the level of radiologist expertise can affect interpretation [59]. HRCT proves central in the imaging of classic and emerging pneumoconioses [6,34,60-64], as well as differentiating occupational lung disease from other ILDs [65,66]. New HRCT findings are revealing additional imaging characteristics important to the diagnosis of occupational lung disease [67-70]. A negative chest CT also proves useful in excluding disease [71]. The International Classification of High-Resolution Computed Tomography for Occupational and Environmental Respiratory Diseases recently demonstrated correlation with physiologic testing [72]. Finally, CT imaging findings can provide prognostic value [73]. CT with IV contrast serves no purpose in the setting of suspected ILD.

MRI Chest
There is limited research supporting the use of MRI in occupational lung disease, none of which supports the use of MRI as the initial imaging.

FDG-PET/CT Skull Base to Mid-Thigh
There is no relevant literature to support the use of FDG-PET/CT in the initial imaging evaluation of suspected occupation-associated ILD.

Variant 3: Occupational exposure, suspected interstitial lung disease based on radiography. Next imaging study.

CT Chest
Chest radiography performed for screening, surveillance, or diagnostic reasons may reveal findings characteristic of occupational lung disease or nonspecific findings in the setting of reported occupational exposure [43,56]. When ILD is suspected on radiographs, chest HRCT again plays the central role in imaging diagnosis, not only further characterizing true lung disease but also increasing specificity by identifying false-positives [57,74]. As noted above, the use of chest CT to diagnose occupation-related ILD may avoid the need for lung biopsy, differentiate occupational lung disease from other diffuse lung diseases [66,73], and identify emerging occupational lung diseases [34,60-63]. CT findings in occupational lung disease may correlate with physiologic testing [72] and assist in determining prognosis [73]. CT with IV contrast serves no purpose in the setting of suspected ILD. However, IV contrast can be helpful in identifying nonpulmonary manifestations of occupational exposure.

MRI Chest
Select fast MRI sequences have approached the image quality of CT in characterizing progressive massive fibrosis in the setting of pneumoconiosis [75]. A few recent studies have evaluated MRI for identifying ILD to include the use of 3T MRI with and without IV contrast in the setting of pulmonary fibrosis [51,53] and 1.5T MRI in systemic

sclerosis [52], suggesting feasibility for differentiating normal lung from ILD. However, MRI has not been specifically studied for imaging of suspected occupation-associated ILD based on radiography.

FDG-PET/CT Skull Base to Mid-Thigh
There is no relevant literature to support the use of FDG-PET/CT in the evaluation of population-based screening and surveillance of occupational lung disease.

Image-Guided Transthoracic Needle Biopsy
There is no relevant literature to support the use of image-guided transthoracic needle biopsy for the evaluation of the diagnosis of ILD based on radiography.

Variant 4: Occupational exposure, suspected airway disease. Initial imaging.

Radiography Chest
Similar to suspected ILD, chest radiography serves a complementary role to chest HRCT in the evaluation of suspected airway disease, although airway findings, if present, are nonspecific on chest radiography [21,24,54,55]. Chest radiography primarily excludes alternative or complicating diagnoses, such as infectious pneumonia or pulmonary edema, with HRCT providing the best imaging characterization of airway disease.

CT Chest
Hypersensitivity pneumonitis typically presents with a combination of pneumonitis and small airway obstruction, producing characteristic findings on chest HRCT with expiratory imaging [76,77]. New and changing occupational exposures causing hypersensitivity pneumonitis are continually described, highlighting the importance of high clinical suspicion and evaluation with HRCT [33,78,79]. Imaging features of hypersensitivity pneumonitis on HRCT also provide predictive information regarding disease behavior [68,80-90] and drive treatment decisions [91].

Certain occupational inhalational exposures, such as diacetyl acetate and carbon dust, may lead to more isolated airway disease, such as constrictive bronchiolitis, bronchial anthracofibrosis, and occupational asthma. Various occupations, such as flavoring microwave popcorn, processing coffee, and serving on military deployment to Iraq/Afghanistan, can result in constrictive bronchiolitis [29-31] evident on HRCT with expiratory imaging [92]. Of note, a few studies over time have demonstrated the importance of tissue biopsy in the setting of negative HRCT but clinically suspected occupational small airway disease [30,93]. In large airway disease, CT may assist in certain diagnoses, such as isolated bronchial anthracofibrosis [35,93,94], although medical imaging has limited value in occupational asthma outside of diagnosing alternative disease. CT with IV contrast serves no purpose in the setting of suspected occupational airway disease.

MRI Chest
No specific studies have examined the use of MRI in the setting of occupation-associated airway disease. Although substantial literature supports research and clinical use of MRI for the study of other large and small airway diseases, such as chronic obstructive airway disease, asthma, lung transplant, and cystic fibrosis. [95-100].

FDG-PET/CT Skull Base to Mid-Thigh
There is no relevant literature to support the use of FDG-PET/CT in the initial imaging evaluation of suspected occupation-associated airway lung disease.

Variant 5: Confirmed occupational lung disease, suspected thoracic neoplasm.

CT Chest
Several occupational exposures increase the risk for thoracic malignancies, the most common being mesothelioma and primary lung carcinoma. The association of malignancy with asbestos exposure is well known, but other occupational lung diseases also demonstrate increased rates of lung cancer [101,102]. Because of this increased risk, evaluation of occupational lung disease requires an increased level of suspicion for malignancy and may warrant the use of advanced imaging. Characteristic CT imaging features may help differentiate occupational lung disease from thoracic neoplasm, with additional CT imaging benefits to include potential for cancer screening, risk stratification, and guidance for biopsy [103-111]. As further discussed and supported in the ACR Appropriateness Criteria® topic on "Noninvasive Clinical Staging of Primary Lung Cancer" [112], CT chest with IV contrast is recommended for initial imaging because of improved characterization of direct extrapulmonary tumor invasion and thoracic metastatic disease. Additionally, contrast enhancement increases sensitivity of primary or metastatic pleural malignancies [111]. CT chest without IV contrast is "Usually Appropriate" for initial evaluation of suspected

neoplasm but generally in the context of additional complementary imaging [112]. Chest CT has known limitations for diagnosis of malignancy, often requiring alternative imaging assessment or diagnostic testing [109,111].

MRI Chest

MRI has been shown in some small studies to be useful in the setting of occupational lung disease and suspected malignancy. For instance, it can be helpful in differentiating progressive massive fibrosis from malignancy [113], characterizing known pleural mesothelioma [114,115], and distinguishing benign from malignant lymphadenopathy [116]. MRI chest with and without contrast is recommended over MRI chest without contrast for increased detection and characterization of pleural malignancy, particularly for mesothelioma diagnosis [117].

FDG-PET/CT Skull Base to Mid-Thigh

Recent studies reveal mixed potential benefit of PET/CT for the evaluation of potential malignancy complicating occupational lung disease. PET/CT poorly differentiates benign from malignant changes in progressive massive fibrosis [118,119] but can provide benefit in the diagnosis of pleural and lung malignancies in asbestos exposure [120-122]. The decision between CT surveillance, PET/CT, and lesion biopsy is generally situational and should be determined in the setting of multidisciplinary discussions.

Image-Guided Transthoracic Needle Biopsy

Transthoracic needle biopsy is a well-established diagnostic test in the workup of suspected thoracic neoplasm, with diagnostic accuracy ranging from 77% to 93% [123-125]. Selection of image-guided transthoracic needle biopsy over bronchoscopic biopsy or surgical excision biopsy depends on a number of variables, such as location, size, and distant disease. Research studies examining detection of malignancy by imaging often use transthoracic needle biopsy as a gold standard [104,113,118], although no literature currently addresses the effect of diffuse occupational lung disease on the sensitivity or specificity of transthoracic needle biopsy.

Radiography Chest

Chest radiographs play a complementary role to additional imaging in the evaluation of suspected thoracic neoplasm but alone prove inadequate for the detection of pulmonary malignancy in occupational lung disease [126].

Summary of Recommendations

- **Variant 1**: Radiography of the chest is usually appropriate for the initial imaging of patients who undergo screening and surveillance for lung disease when occupational exposure is present.
- **Variant 2**: Chest CT without IV contrast and radiographs of the chest are usually appropriate for the initial imaging of patients when occupational exposure is present with suspected ILD. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care.)
- **Variant 3**: Chest CT without IV contrast is usually appropriate as the next imaging study for patients when occupational exposure is present with suspected ILD based on radiography.
- **Variant 4**: Chest CT without IV contrast and radiographs of the chest are usually appropriate for the initial imaging of patients when occupational exposure is present with suspected airway disease. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care.)
- **Variant 5**: Chest CT with IV contrast and image-guided transthoracic needle biopsy are usually appropriate for patients with confirmed occupational lung disease and suspected thoracic neoplasm. These procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care.)

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

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

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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, because of both 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 with 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 [127].

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 "Varies."		

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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.