

**American College of Radiology**  
**ACR Appropriateness Criteria®**  
**Chronic Dyspnea-Noncardiovascular Origin**

**Variant: 1 Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	●
CT chest without IV contrast	May Be Appropriate (Disagreement)	●●●
US chest	Usually Not Appropriate	○
Fluoroscopy chest	Usually Not Appropriate	●●●
MRI chest without and with IV contrast	Usually Not Appropriate	○
MRI chest without IV contrast	Usually Not 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	●●●●

**Variant: 2 Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	●
CT chest without IV contrast	Usually Appropriate	●●●
US chest	Usually Not Appropriate	○
Fluoroscopy chest	Usually Not Appropriate	●●●
MRI chest without and with IV contrast	Usually Not Appropriate	○
MRI chest without IV contrast	Usually Not Appropriate	○
CT chest with IV contrast	Usually Not Appropriate	●●●
CT chest without and with IV contrast	Usually Not Appropriate	●●●
V/Q scan lung	Usually Not Appropriate	●●●
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	●●●●

**Variant: 3 Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	●
CT chest without IV contrast	Usually Appropriate	●●●
US chest	Usually Not Appropriate	○
Fluoroscopy chest	Usually Not Appropriate	●●●
MRI chest without and with IV contrast	Usually Not Appropriate	○
MRI chest without IV contrast	Usually Not 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	●●●●

**Variant: 4 Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial**

## imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	⌚
CT chest without IV contrast	Usually Appropriate	⌚⌚⌚
US chest	Usually Not Appropriate	⌚
Fluoroscopy chest	Usually Not Appropriate	⌚⌚⌚⌚
MRI chest without and with IV contrast	Usually Not Appropriate	⌚
MRI chest without IV contrast	Usually Not 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	⌚⌚⌚⌚⌚

## Variant: 5 Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	⌚
CT chest with IV contrast	Usually Appropriate	⌚⌚⌚⌚
CT chest without IV contrast	Usually Appropriate	⌚⌚⌚⌚
US chest	Usually Not Appropriate	⌚
Fluoroscopy chest	Usually Not Appropriate	⌚⌚⌚⌚
MRI chest without and with IV contrast	Usually Not Appropriate	⌚
MRI chest without 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	⌚⌚⌚⌚⌚

## Variant: 6 Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	⌚
CT chest with IV contrast	May Be Appropriate	⌚⌚⌚⌚
CT chest without IV contrast	May Be Appropriate	⌚⌚⌚⌚
US chest	Usually Not Appropriate	⌚
Fluoroscopy chest	Usually Not Appropriate	⌚⌚⌚⌚
MRI chest without and with IV contrast	Usually Not Appropriate	⌚
MRI chest without IV contrast	Usually Not Appropriate	⌚
CT chest without and with IV contrast	Usually Not Appropriate	⌚⌚⌚⌚

## Panel Members

Jared D. Christensen, MD, MBA<sup>a</sup>, Michael Harowicz, MD<sup>b</sup>, Christopher M. Walker, MD<sup>c</sup>, Brent P. Little, MD<sup>d</sup>, Kiran Batra, MD<sup>e</sup>, Anupama G. Brixey, MD<sup>f</sup>, Melissa B. Carroll, MD<sup>g</sup>, Lydia Chelala, MD<sup>h</sup>, Christian W. Cox, MD<sup>i</sup>, M. Bradley Drummond, MD, MHS<sup>j</sup>, Nicole M. Geissen, DO<sup>k</sup>, Jason Halpern, MD<sup>l</sup>, Rachna Madan, MBBS<sup>m</sup>, Venu Pararath Gopalakrishnan, MD<sup>n</sup>, Girish S. Shroff, MD<sup>o</sup>, Christina S. Thornton, MD, PhD<sup>p</sup>, Jennifer Zreloff, MD<sup>q</sup>, Jonathan H. Chung, MD<sup>r</sup>

## Summary of Literature Review

## Introduction/Background

Dyspnea is "a subjective experience of breathing discomfort" [1], often described as a feeling of breathlessness or shortness of breath that varies in intensity. This complex symptom accounts for 1 in 4 ambulatory patient encounters and is caused by a wide range of physiological, psychological, social, behavioral, and environmental factors. In patients without an established diagnosis, clinical history and physical examination may provide initial insight into the cause or causes of dyspnea, however, laboratory, radiological, and other ancillary tests are frequently needed to establish a diagnosis [1].

Chronic dyspnea is defined by shortness of breath for >4 to 8 weeks [1,2]. The differential diagnosis for chronic dyspnea is broad and includes pulmonary, cardiac, gastrointestinal, neuromuscular, systemic, and psychiatric etiologies. The majority of cases are pulmonary or cardiac-related, with approximately 85% attributable to congestive heart failure, myocardial ischemia, or chronic obstructive pulmonary disease (COPD) with a minority of these cases related to infection or other pathology [3]. Chronic dyspnea can be associated with a wide variety of disorders involving the airways, alveoli, interstitium, pulmonary vessels, mediastinum and hila, pleura, diaphragm, and chest wall [2]. Over 30% of cases are multifactorial [3]. Chronic dyspnea related to pulmonary embolism, cardiovascular, large airways, and diffuse lung diseases are not addressed in this document. See the ACR Appropriateness Criteria® topics on "[Suspected Pulmonary Embolism](#)" [4], "[Dyspnea-Suspected Cardiac Origin \(Ischemia Already Excluded\)](#)" [5], "[Suspected Pulmonary Hypertension](#)" [6], and "[Diffuse Lung Disease](#)" [7] for further details.

## Special Imaging Considerations

Inspiratory and expiratory CT chest may have a role in the evaluation for chronic dyspnea, specifically to evaluate for air trapping on expiratory images. Air trapping is associated with lung function impairment in patients with small airways disease, including in association with asthma and COPD [8-10], history of COVID-19 infection [11-13], and other small airways disease subtypes [14,15].

The use of hyperpolarized xenon gas for functional and quantitative MRI (Xenon-MRI) has recently received FDA approval in the United States. Studies have shown that Xenon-MRI may show impaired ventilation in patients with a history of COVID-19 infection, COPD, and small airways disease [16-24].

Bedside point-of-care ultrasound (POCUS) is considered an extension of the physical examination. It is distinct from diagnostic ultrasound (US) imaging and is not considered a procedure in evaluating noncardiovascular causes of chronic dyspnea. POCUS may be used for the rapid assessment of critical conditions in the setting of limited access to diagnostic imaging or when the patient's disposition or mobility precludes transportation to diagnostic imaging suites. POCUS should be performed by trained professionals for specific pulmonary and cardiovascular indications and may be useful in directing further clinical or imaging assessment [25].

## Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the

initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously wherein each procedure provides unique clinical information to effectively manage the patient's care).

## **Discussion of Procedures by Variant**

### **Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

Etiologies producing chronic dyspnea are broad. The goal of initial imaging is to identify findings that may indicate a specific diagnosis, narrow differential considerations, define structural anatomy, and identify potential associated complications. Imaging aids in triage and directing management so that patients may receive timely and appropriate treatment or additional evaluation.

### **Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

#### **A. CT chest with IV contrast**

Venous phase CT chest with intravenous (IV) contrast usually does not have a role in the initial evaluation of nonspecific chronic dyspnea unless a vascular abnormality is suspected. Although it may be beneficial in specific clinical situations, CT chest with IV contrast is not included in guidelines for the initial workup of chronic dyspnea [2,3]. CT angiography (CTA) is a distinct imaging procedure and is also not indicated for the evaluation of noncardiovascular causes of chronic dyspnea. If chronic pulmonary embolism is a suspected source for chronic dyspnea, see the ACR Appropriateness Criteria® topic on "[Suspected Pulmonary Hypertension](#)"[6].

### **Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

#### **B. CT chest without and with IV contrast**

CT chest without and with IV contrast does not have added value in the workup of chronic dyspnea compared to a CT chest with IV contrast or CT chest without IV contrast alone.

### **Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

#### **C. CT chest without IV contrast**

CT chest without IV contrast has a higher sensitivity and specificity than chest radiography for detecting clinically relevant pathology and is considered an excellent tool to evaluate the airways, pulmonary parenchyma, and interstitium in the setting of dyspnea or suspected diffuse lung disease. Although typically not indicated for initial imaging, CT chest without IV contrast may be indicated in the setting of abnormal chest radiographs or in patients with a normal chest radiograph but persistent symptoms [26,27]. A study evaluating an algorithmic approach to chronic dyspnea by Pratter et al [28] recommends CT chest without IV contrast as a second-line imaging study after clinical evaluation and chest radiography, however, the usefulness of CT was found to be limited with diagnosis routinely requiring additional testing.

### **Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

#### **D. 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 in the evaluation of chronic dyspnea of uncertain etiology.

**Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

**E. Fluoroscopy chest**

There is no relevant literature to support the use of fluoroscopy chest in the evaluation of chronic dyspnea of uncertain etiology.

**Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

**F. MRI chest without and with IV contrast**

There is no relevant literature to support the use of MRI chest without and with IV contrast in the evaluation of chronic dyspnea of uncertain etiology.

**Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

**G. MRI chest without IV contrast**

There is no relevant literature to support the use of MRI chest without IV contrast in the evaluation of chronic dyspnea of uncertain etiology.

**Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

**H. Radiography chest**

Chest radiography is the first-line imaging examination for the evaluation of patients with chronic dyspnea [28]. It is considered an essential component of the first-tier initial workup along with a comprehensive history, physical, and clinical evaluation, such as pulmonary function testing. Chest radiography, in conjunction with appropriate laboratory and clinical studies, can establish a diagnosis in one-third of cases or guide the need for additional diagnostic testing [2,3,29].

Posterior-anterior (PA) and lateral chest radiography is typically of higher quality and is preferred over single projection PA or anterior-posterior (AP) portable radiography. Chest radiography may reveal a wide variety of abnormalities in chronic dyspnea that can guide further imaging choices as outlined in subsequent variants. including findings suggestive of infection or pleural, chest wall, or diaphragmatic pathology.

**Variant 1: Adult. Chronic dyspnea. Unclear etiology. Initial imaging.**

**I. US chest**

US of the chest has limited data to support its role in the initial workup of chronic dyspnea. However, it can provide a rapid evaluation of some pleural diseases and may be beneficial for very specific indications in the acute setting, most studies suggest an otherwise limited role for initial imaging of chronic dyspnea [30-32].

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

In the setting of suspected COPD, the goals of initial imaging are to detect and characterize the extent of disease. Initial imaging aids in confirming the diagnosis, assessing disease severity, and guiding appropriate management strategies. Patients may benefit from the timely implementation of COPD-specific therapies resulting in symptom relief, improved lung function, and enhanced quality of life.

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

**A. CT chest with IV contrast**

Venous phase CT chest with IV contrast has limited added value in the initial imaging of COPD compared to chest CT without IV contrast. CTA is a distinct imaging procedure and has no indicated role in initial evaluation of noncardiovascular causes of chronic dyspnea. Dual-energy CT may have a role for the preoperative assessment of perfusion in COPD, although it is not indicated for initial evaluation [33].

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

**B. CT chest without and with IV contrast**

CT chest without and with IV contrast does not have added value in the workup of COPD compared to a CT chest with IV contrast or CT chest without IV contrast.

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

**C. CT chest without IV contrast**

CT chest without IV contrast is considered useful as an initial imaging in symptomatic patients with a high clinical suspicion for COPD. CT has greater sensitivity and specificity than chest radiography in determining the type, extent, and distribution of emphysema and bronchial wall abnormalities, which can relate to morbidity and mortality [34-36]. Furthermore, CT can identify early imaging changes of COPD in symptomatic patients not meeting clinical criteria for COPD and in asymptomatic patients who smoke but have normal pulmonary function [37-42]. Visual assessments of emphysema and airway disease at CT are accurate and reproducible [43]. In addition, quantitative CT-derived parameters correlate with pulmonary function tests and can be used as imaging biomarkers to follow disease progression [44-48]. Findings at CT have been shown to correlate with COPD clinical exacerbations, patient-reported symptomology [49-52], and to predict health status [53,54]. CT-based COPD phenotypes have prognostic value in predicting future hospitalization, symptomatic decline, and mortality [55,56]. Expiratory CT, although not indicated for the initial evaluation of COPD, may quantify the degree of airflow limitation and correlate with dyspnea severity [57]. CT chest could additionally aid in excluding alternative etiologies or co-morbidities that may contribute to the patient's chronic dyspnea such as cardiovascular etiologies, infectious or neoplastic complications, and diffuse lung diseases.

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

**D. 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 chronic dyspnea with suspected COPD.

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

**E. Fluoroscopy chest**

Fluoroscopy may have a role in evaluating diaphragmatic complications of COPD, but there is no supporting evidence for its use as an initial imaging study for COPD diagnosis.

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD). Initial imaging.**

**F. MRI chest without and with IV contrast**

There is no relevant literature to support the use of MRI chest without and with IV contrast in the evaluation of chronic dyspnea with suspected COPD.

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD).****Initial imaging.****G. MRI chest without IV contrast**

Numerous MRI techniques are available to characterize COPD, although most are predominantly research applications including hyperpolarized helium, T1 oxygen-enhanced mapping, and equilibrium signal mapping [58-60]. Some studies have shown good correlation of MRI quantitative imaging with CT-derived and clinical measures. [58-60]. Xenon-MRI is recently FDA-approved and may have a role in evaluating impaired ventilation in COPD but is not indicated for initial imaging [16,19].

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD).****Initial imaging.****H. Radiography chest**

Chest radiography is endorsed as a useful first-line imaging study for patients with chronic dyspnea and suspected COPD because there are multiple radiographic findings that can aid the diagnosis [19,39]. Chest radiographs can help exclude alternative diagnoses and evaluate for comorbidities and COPD complications [61]. Wallace et al [62] reported that for chest radiographs performed during COPD evaluation, 14% detected potentially treatable causes of dyspnea other than COPD or lung cancer, and 84% of radiographs aided in management. Potentially treatable causes included lower tract respiratory infections, bronchiectasis, pulmonary fibrosis, pleural effusion, left ventricular failure, and active tuberculosis. PA and lateral chest radiography is typically of higher quality and is preferred over AP portable radiography, when feasible.

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD).****Initial imaging.****I. US chest**

US may have a role in defining pleural or diaphragmatic complications related to COPD, but there is little supporting evidence for its use as an initial diagnostic technique for this condition [63].

**Variant 2: Adult. Chronic dyspnea. Suspected chronic obstructive pulmonary disease (COPD).****Initial imaging.****J. V/Q scan lung**

There is no relevant literature to support the use of ventilation-perfusion (V/Q) lung scan in the initial evaluation of chronic dyspnea with suspected COPD.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.**

In the setting of suspected small airways disease as a cause of chronic dyspnea, the goal of initial imaging is to confirm the diagnosis, suggest underlying etiologies, and guide patient care management. Because the small airways are not directly visualized, imaging findings are typically secondary manifestations that help differentiate small airways pathology from other respiratory conditions. By identifying and characterizing small airways disease, imaging may direct optimal treatment, reduce delays in care, and optimize therapies aimed to improve respiratory symptoms and lung function by alleviating small airways inflammation or obstruction.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****A. CT chest with IV contrast**

Venous phase IV contrast chest CT has limited added value compared to chest CT without IV contrast in the workup of small airways disease. CTA is a distinct imaging procedure and has no indicated role in evaluating noncardiovascular causes of chronic dyspnea.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****B. CT chest without and with IV contrast**

CT without and with IV contrast does not have added value in the workup of small airways disease compared to a CT chest with IV contrast or CT chest without IV contrast.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****C. CT chest without IV contrast**

Chest CT without IV contrast may be indicated as an initial imaging examination in the setting of unexplained chronic dyspnea when small airways disease is a suspected etiology. Although the small airways cannot be directly visualized at chest CT, the modality allows for the evaluation of secondary findings related to small airways disease. Mosaic lung attenuation (on inspiratory CT) and confirmed air trapping (on expiratory CT) can commonly be seen in asthma and COPD but are also findings associated with other many diseases affecting the small airways [14,15]. Small airways disease can also manifest with centrilobular nodularity, tree-in-bud nodularity, or ground glass opacities, which are readily assessed on chest CT without IV contrast and can aid in directing management [64,65]. CT can also diagnose other conditions with symptoms similar to small airways disease.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****D. 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 chronic dyspnea with suspected small airways disease.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****E. Fluoroscopy chest**

There is no relevant literature to support the use of fluoroscopy chest in the evaluation of chronic dyspnea with suspected small airways disease.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****F. MRI chest without and with IV contrast**

There is no relevant literature to support the use of MRI chest without and with IV contrast in the evaluation of chronic dyspnea with suspected small airways disease.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****G. MRI chest without IV contrast**

There is no relevant literature to support the use of MRI chest without IV contrast in the evaluation of small airways disease. Xenon-MRI is FDA approved and may have a role in the evaluation of impaired ventilation in small airways disease but is not indicated for initial imaging [18].

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****H. Radiography chest**

Though there is no primary evidence to support chest radiography as part of the initial workup of small airways disease, radiographs usually have a role in helping to exclude other pathology as a cause of dyspnea, including edema, infection, and pulmonary fibrosis. PA and lateral chest radiography is typically of higher quality and is preferred over AP portable radiography, when feasible.

**Variant 3: Adult. Chronic dyspnea. Suspected small airways disease. Initial imaging.****I. US chest**

There is no relevant literature to support the use of US chest in the evaluation of chronic dyspnea with suspected small airways disease.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

In patients with known or suspected prior COVID-19 infection presenting with chronic dyspnea, initial imaging aims to assess and characterize the extent of pulmonary manifestations associated with COVID-19, including ground-glass opacities, consolidation, and findings of fibrosis. Imaging aids in diagnosing COVID-19 infection, excluding other causes of chronic dyspnea, and guiding management. From the patient's perspective, timely imaging reduces delays in appropriate treatment, hastening clinical improvement, and minimizing the risk of long-term respiratory complications.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**A. CT chest with IV contrast**

Venous phase CT chest with IV contrast has limited added value in post-COVID patients compared to standard CT chest without IV contrast, although it may have a role in specific clinical situations. CTA is a distinct imaging procedure and may be useful for the assessment of chronic pulmonary embolism as a source of chronic dyspnea in the setting of prior COVID-19 infection, however, it has no indicated role in evaluating noncardiovascular causes of chronic dyspnea.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**B. CT chest without and with IV contrast**

CT without and with IV contrast does not have added value in the initial workup of patients after known COVID-19 infection compared to CT chest with IV contrast or CT chest without IV contrast.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**C. CT chest without IV contrast**

CT chest without IV contrast is a useful initial imaging examination in symptomatic patients with known or suspected prior COVID-19 infection. Numerous studies indicate that CT readily demonstrates findings related to chronic dyspnea post-COVID-19 infection including persistent consolidation, ground-glass opacities, organizing pneumonia, or pulmonary fibrosis [66-71]. CT can be useful in determining the trajectory or plateauing of lung healing in patients with these findings. Patients have also been shown to have air trapping after COVID-19 infection, which can be evaluated with the addition of expiratory images [11-13]. Consideration for obtaining a dedicated interstitial lung disease protocol may be reasonable based on the degree of clinical suspicion for fibrosis, symptoms, and severity of past COVID-19 infection (see ACR Appropriateness Criteria® topic on "[Diffuse Lung Disease](#)" [7] for further guidance). Persistent CT abnormalities are more common in patients who had a severe infection requiring hospitalization [72-79]. There is heterogeneity in the literature with respect to the prevalence of imaging findings after COVID-19 infection; chest CT may, therefore, be most useful for symptomatic patients with a confirmed history of moderate to severe infection [80,81].

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**D. 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 chronic dyspnea with known or suspected COVID-19 infection.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**E. Fluoroscopy chest**

There is no relevant literature to support the use of fluoroscopy chest in the evaluation of chronic dyspnea with known or suspected COVID-19 infection.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**F. MRI chest without and with IV contrast**

There is no relevant literature to support the use of MRI chest without and with IV contrast in the evaluation of chronic dyspnea with known or suspected COVID-19 infection.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**G. MRI chest without IV contrast**

There is limited data to suggest a role for standard chest MRI without IV contrast in the initial workup of patients after COVID-19 infection. Studies have shown MRI can diagnose findings of fibrosis and persistent opacities in patients recovered from COVID-19, however, diagnostic usefulness beyond chest CT has not been established [82,83]. Xenon-MRI is FDA-approved and may have a role in evaluating for impaired ventilation in symptomatic patients post-COVID-19 infection [20-22].

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**H. Radiography chest**

Radiography is considered a useful initial imaging examination for patients with persistent symptoms post-COVID-19 infection because 13.8% to 38% of patients, particularly those with a severe disease, had fibrosis or other persistent opacities on chest radiographs 2 to 6 months after COVID-19 diagnosis [78,84,85]. PA and lateral chest radiography is typically of higher quality and is preferred over AP portable radiography, when feasible.

**Variant 4: Adult. Chronic dyspnea. Known or suspected prior COVID-19 infection. Initial imaging.**

**I. US chest**

US may have a limited role in the initial workup of patients with a history of COVID-19 infection when chest radiography or CT are unavailable or otherwise contraindicated. Lung US has shown parenchymal abnormalities in symptomatic patients 3 to 6 months post-COVID-19 infection, particularly in those who were previously hospitalized [86-90].

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

Where chronic dyspnea due to pleural or chest wall disease is suspected, the goals of initial imaging are to characterize the anatomy and diagnose potential pathology affecting these structures. In addition to morphology and anatomic relationships, imaging can detect relevant diseases involving the pleura, chest wall, and adjacent structures such as masses, fractures, inflammatory changes, or pleural effusions. Imaging facilitates accurate diagnosis and may prompt

more timely and appropriate interventions resulting in improved patient outcomes.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**A. CT chest with IV contrast**

Chest CT with venous phase IV contrast can add additional diagnostic information beyond CT chest without IV contrast in its ability to evaluate for pleural thickening, pleural enhancement, and septations within pleural collections, as can be seen in complex exudative or malignant effusions [91,92]. IV contrast can also be helpful for the diagnosis of malignant disease of the chest wall. The decision to give IV contrast is dictated by the suspected disease process. CTA is a distinct imaging procedure and has no indicated role in evaluating noncardiovascular causes of chronic dyspnea. CTA timed for pulmonary artery evaluation (pulmonary embolism protocol) frequently does not show pleural abnormalities due to the differences in contrast timing compared to a venous phase CT.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**B. CT chest without and with IV contrast**

Whereas CT is excellent in detecting and characterizing pleural disease, performing CT without and with IV contrast does not have added value compared to CT chest with IV contrast or CT chest without IV contrast.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**C. CT chest without IV contrast**

CT is superior to radiography in detecting and characterizing pleural disease, differentiating it from parenchymal and chest wall disease, and determining the extent of involvement [93]. Like radiography, CT is limited in its ability to differentiate causes of pleural effusion, although the presence of pleural thickening and septations can be seen in complex exudative or malignant effusions [91,92]. Although CT is superior to radiography, adding IV contrast to CT can be helpful in assessing pleural enhancement and in the evaluation of chest wall masses.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**D. FDG-PET/CT skull base to mid-thigh**

FDG-PET/CT is a secondary test that may be used in the staging of mesothelioma and pleural metastatic disease.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**E. Fluoroscopy chest**

There is no relevant literature to support the use of fluoroscopy chest in the evaluation of chronic dyspnea with suspected disease of the pleura or chest wall.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**F. MRI chest without and with IV contrast**

The addition of IV contrast to conventional chest MRI can further improve soft-tissue contrast facilitating assessment of complex anatomic relationships in the setting of pleural, chest wall, or

mediastinal malignancy.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**G. MRI chest without IV contrast**

Compared to CT, MRI may provide improved characterization and assessment of the extent of pleural and chest wall abnormalities that may contribute to chronic dyspnea but is not typically recommended for initial imaging. MRI can help distinguish components of complex fluid collections, including septations [94], and is thought to be slightly better at distinguishing benign from malignant pleural thickening [95]. Intrinsic soft tissue contrast demonstrates anatomic relationships and facilitates the assessment of invasion and neurovascular encasement in the setting of malignancy. Studies have shown that MRI can be helpful in planning surgical chest wall reconstruction and the diagnosis and management of pectus excavatum [96].

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**H. Radiography chest**

Chest radiography is a reasonable initial imaging study in the setting of suspected pleural or chest wall pathology causing chronic dyspnea. Pleural effusion is a common pathologic process and can readily be diagnosed and quantified on chest radiographs, although the precise cause of the effusion cannot typically be determined [97]. Chest radiography is also somewhat limited in its ability to precisely localize an abnormality, whether parenchymal, pleural, or extrapleural. In addition to pleural disease, a chest radiograph may reveal structural abnormalities of the sternum, ribs, and thoracic spine that may predispose toward dyspnea or may diagnose other conditions masquerading as pleural or chest wall pathology. PA and lateral chest radiography is typically of higher quality and is preferred over AP portable radiography, when feasible.

**Variant 5: Adult. Chronic dyspnea. Suspected disease of the pleura or chest wall. Initial imaging.**

**I. US chest**

US can complement the imaging evaluation of several pleural or chest wall abnormalities. US has an established role in pleural effusion, including detection, differentiation from lung disease, characterization, and guidance of intervention. US may be more effective than chest radiography and CT at detecting internal septations in complex pleural collections [98]. US may also be indicated for evaluating pleural thickening, plaques, and palpable masses. Though POCUS may be useful in some clinical contexts, such as the bedside diagnosis or characterization of pleural effusion or pneumothorax, diagnostic US is not recommended for the initial evaluation of pleural or chest wall disease in the setting of chronic dyspnea [99].

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

For chronic dyspnea suspected to be caused by diaphragm dysfunction, the goals of initial imaging are to evaluate the structure, integrity, and function of the diaphragm and to identify associated complications. Imaging helps differentiate diaphragmatic disease from pulmonary causes of respiratory dysfunction and facilitates directing appropriate medical or surgical management. Patients may benefit from timely and targeted interventions that optimize diaphragm function and improve or alleviate symptoms.

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**A. CT chest with IV contrast**

CT chest venous phase has limited added value compared to standard CT chest without IV contrast in evaluating diaphragm dysfunction but may be useful in the setting of suspected etiologies of phrenic nerve impairment, such as iatrogenic injury or complications by a regional mass. CTA is a distinct imaging procedure and has no indicated role in evaluating noncardiovascular causes of chronic dyspnea.

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**B. CT chest without and with IV contrast**

CT without and with IV contrast does not have added value compared to CT chest with IV contrast or CT chest without IV contrast in the evaluation of diaphragmatic dysfunction.

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**C. CT chest without IV contrast**

CT may be useful for initial imaging of diaphragmatic dysfunction in certain clinical contexts. CT can detect abnormal diaphragm positioning (elevation or eventration), diaphragmatic hernias, and markers of potential diaphragm dysfunction including atrophy of the diaphragmatic crus and evaluation of the course of the phrenic nerve [100].

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**D. Fluoroscopy chest**

Fluoroscopy allows for accurate assessment of diaphragmatic movement in real-time and can confirm suspected diaphragmatic paralysis after initial imaging via lack of or reduced orthograde excursion with deep inspiration and resultant paradoxical motion with sniffing. It is useful as a secondary evaluation for focused functional assessment following chest radiography or CT [101,102].

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**E. MRI chest without and with IV contrast**

Chest MRI with IV contrast does not have added value for the dynamic assessment of diaphragmatic motion [103].

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**F. MRI chest without IV contrast**

Cine dynamic MRI sequences allow for the direct visualization of diaphragm motion [104]. Although this technique can provide a comprehensive analysis of both the diaphragm and chest wall muscle movement in neuromuscular diseases, MRI is not typically indicated for initial imaging [105].

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**G. Radiography chest**

A static chest radiograph is a useful initial examination for assessing the relative position of the diaphragm and abnormal diaphragm contours, including elevation, eventration, and hernias, and their effect on lung volumes. It may suggest diaphragmatic paralysis when compared to a fluoroscopic reference standard [106]. Chest radiography can also diagnose other conditions initially thought to represent diaphragmatic dysfunction. In the outpatient setting, PA and lateral chest radiography is typically of higher quality and is preferred over AP portable radiography.

**Variant 6: Adult. Chronic dyspnea. Suspected diaphragm dysfunction. Initial imaging.**

**H. US chest**

Diagnostic US findings are concordant with fluoroscopic imaging of diaphragm motion in the setting of suspected diaphragmatic dysfunction [107]. It is usually not useful for initial imaging but can be a helpful secondary study for dynamic assessment. Diaphragmatic excursion amplitude, thickness, and contraction can be evaluated, and paralysis may be identified as paradoxical movement during respiration [108]. There is high sensitivity and specificity for the diagnosis of neuromuscular disorders of the diaphragm [109-112]. The extent of diaphragm motion in various conditions, including neuromuscular diseases, COPD, and interstitial lung disease, correlates with respiratory symptoms and lung function [113-117].

## Summary of Highlights

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- **Variant 1:** Chest radiography is usually appropriate as the first-line imaging modality for patients with chronic dyspnea with unclear etiology. Chest CT without IV contrast may be appropriate as a second-line option if the chest radiograph is abnormal or if there are persistent symptoms.
- **Variants 2, 3, and 4:** Chest radiography is usually appropriate as the first-line imaging modality for patients with chronic dyspnea with suspected COPD, suspected small airways disease, or known/suspected prior COVID-19 infection. Chest CT without IV contrast is usually appropriate as a second-line option if the chest radiograph is abnormal or if there are persistent symptoms.
- **Variant 5:** Chest radiography is usually appropriate as the first-line imaging modality for patients with chronic dyspnea with suspected disease of the pleura or chest wall. CT chest without IV contrast or CT chest with IV contrast (one or the other) is usually appropriate as a second-line option if the chest radiograph is abnormal or if there are persistent symptoms.
- **Variant 6:** Chest radiography is usually appropriate as the first-line imaging modality for patients with chronic dyspnea with suspected diaphragm dysfunction. CT chest without IV contrast or CT chest with IV contrast (one or the other) may be appropriate as a second-line option if the chest radiograph is abnormal or if there are persistent symptoms. Fluoroscopy is useful as a secondary evaluation for focused functional assessment following chest radiography or CT.

## 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, please go to the ACR website at <https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria>.

## Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that predates the use of the current understanding of language inclusive of diversity in sex, intersex, gender, and gender-diverse people. The data variables regarding sex and gender used in

the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health.

## 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.

## Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
0	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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies.”

## References

1. Parshall MB, Schwartzstein RM, Adams L, et al. An official American Thoracic Society statement: update on the mechanisms, assessment, and management of dyspnea. *Am J Respir Crit Care Med.* 2012;185(4):435-452.
2. Karnani NG, Reisfield GM, Wilson GR. Evaluation of chronic dyspnea. *Am Fam Physician.* 2005;71(8):1529-1537.
3. Wahls SA. Causes and evaluation of chronic dyspnea. *Am Fam Physician.* 2012;86(2):173-182.
4. Kirsch J, Wu CC, Bolen MA, et al. ACR Appropriateness Criteria® Suspected Pulmonary Embolism: 2022 Update. *J Am Coll Radiol* 2022;19:S488-S501.
5. Bolen MA, Bin Saeedan MN, Rajiah P, et al. ACR Appropriateness Criteria® Dyspnea-Suspected Cardiac Origin (Ischemia Already Excluded): 2021 Update. *J Am Coll Radiol* 2022;19:S37-S52.
6. Sirajuddin A, Mirmomen SM, Henry TS, et al. ACR Appropriateness Criteria® Suspected Pulmonary Hypertension: 2022 Update. *J Am Coll Radiol* 2022;19:S502-S12.
7. Hobbs SB, Chung JH, Walker CM, et al. ACR Appropriateness Criteria® Diffuse Lung Disease. *J Am Coll Radiol* 2021;18:S320-S29.
8. Hartley RA, Barker BL, Newby C, et al. Relationship between lung function and quantitative computed tomographic parameters of airway remodeling, air trapping, and emphysema in patients with asthma and chronic obstructive pulmonary disease: A single-center study. *Journal of Allergy & Clinical Immunology.* 137(5):1413-1422.e12, 2016 05.
9. Song L, Leppig JA, Hubner RH, et al. Quantitative CT Analysis in Patients with Pulmonary Emphysema: Do Calculated Differences Between Full Inspiration and Expiration Correlate with Lung Function? *Int J Chron Obstruct Pulmon Dis* 2020;15:1877-86.
10. Gawlitza J, Trinkmann F, Scheffel H, et al. Time to Exhale: Additional Value of Expiratory Chest CT in Chronic Obstructive Pulmonary Disease. *Canadian Respiratory Journal.* 2018;9493504, 2018.
11. Solomon JJ, Heyman B, Ko JP, Condos R, Lynch DA. CT of Post-Acute Lung Complications of COVID-19. [Review]. *Radiology.* 301(2):E383-E395, 2021 11.
12. Marchetti F, Izzi N, Donatelli A, et al. Mid-term follow-up chest CT findings in recovered COVID-19 patients with residual symptoms. *British Journal of Radiology.* 96(1141):20220012, 2023 Jan 01.
13. Franquet T, Gimenez A, Ketai L, et al. Air trapping in COVID-19 patients following hospital discharge: retrospective evaluation with paired inspiratory/expiratory thin-section CT. *European Radiology.* 32(7):4427-4436, 2022 Jul.
14. Konstantinos Katsoulis K, Kostikas K, Kontakiotis T. Techniques for assessing small airways function: Possible applications in asthma and COPD. [Review]. *Respiratory Medicine.* 119:e2-e9, 2016 10.

15. Usmani OS, Singh D, Spinola M, Buzzi A, Barnes PJ. The prevalence of small airways disease in adult asthma: A systematic literature review. [Review]. *Respiratory Medicine*. 116:19-27, 2016 07.
16. Lee SM, Seo JB, Hwang HJ, et al. Assessment of regional emphysema, air-trapping and Xenon-ventilation using dual-energy computed tomography in chronic obstructive pulmonary disease patients. *European Radiology*. 27(7):2818-2827, 2017 Jul.
17. Svenningsen S, Guo F, McCormack DG, Parraga G. Noncystic Fibrosis Bronchiectasis: Regional Abnormalities and Response to Airway Clearance Therapy Using Pulmonary Functional Magnetic Resonance Imaging. *Academic Radiology*. 24(1):4-12, 2017 01.
18. Petousi N, Talbot NP, Pavord I, Robbins PA. Measuring lung function in airways diseases: current and emerging techniques. [Review]. *Thorax*. 74(8):797-805, 2019 08.
19. Sheikh K, Coxson HO, Parraga G. This is what COPD looks like. [Review]. *Respirology*. 21(2):224-36, 2016 Feb.
20. Kooner HK, McIntosh MJ, Matheson AM, et al. Postacute COVID-19 Syndrome: <sup>129</sup>Xe MRI Ventilation Defects and Respiratory Outcomes 1 Year Later. *Radiology*. 307(2):e222557, 2023 04.
21. Matheson AM, McIntosh MJ, Kooner HK, et al. Longitudinal follow-up of postacute COVID-19 syndrome: DLCO, quality-of-life and MRI pulmonary gas-exchange abnormalities. *Thorax*. 78(4):418-421, 2023 04.
22. Matheson AM, McIntosh MJ, Kooner HK, et al. Persistent <sup>129</sup>Xe MRI Pulmonary and CT Vascular Abnormalities in Symptomatic Individuals with Post-acute COVID-19 Syndrome. *Radiology*. 305(2):466-476, 2022 11.
23. Tan S, Saffar B, Wrobel J, Laycock A, Melsom S. Air trapping in small airway diseases: A review of imaging technique and findings with an overview of small airway diseases. [Review]. *Journal of Medical Imaging & Radiation Oncology*. 67(5):499-508, 2023 Aug.
24. Lee GM, Carroll MB, Galvin JR, Walker CM. Mosaic Attenuation Pattern: A Guide to Analysis with HRCT. [Review]. *Radiologic Clinics of North America*. 60(6):963-978, 2022 Nov.
25. Buda N, Mendrala K, Skoczynski S, et al. Basics of Point-of-Care Lung Ultrasonography. *N Engl J Med* 2023;389:e44.
26. Oelsner EC, Lima JA, Kawut SM, et al. Noninvasive tests for the diagnostic evaluation of dyspnea among outpatients: the Multi-Ethnic Study of Atherosclerosis lung study. *Am J Med*. 128(2):171-180.e5, 2015 Feb.
27. Zompatori M, Bna C, Poletti V, et al. Diagnostic imaging of diffuse infiltrative disease of the lung. *Respiration*. 2004; 71(1):4-19.
28. Pratter MR, Abouzgheib W, Akers S, Kass J, Bartter T. An algorithmic approach to chronic dyspnea. *Respir Med*. 2011;105(7):1014-1021.
29. Pratter MR, Curley FJ, Dubois J, Irwin RS. Cause and evaluation of chronic dyspnea in a pulmonary disease clinic. *Arch Intern Med*. 1989; 149(10):2277-2282.
30. Zanforlin A, Tursi F, Marchetti G, et al. Clinical Use and Barriers of Thoracic Ultrasound: A Survey of Italian Pulmonologists. *Respiration*. 99(2):171-176, 2020. *Respiration*. 99(2):171-176, 2020.

31. Gundersen EA, Juhl-Olsen P, Bach A, et al. PrehospitaL Ultrasound in Undifferentiated DyspnEa (PreLUDE): a prospective, clinical, observational study. *Scandinavian Journal of Trauma, Resuscitation & Emergency Medicine*. 31(1):6, 2023 Feb 05.
32. Rogoza K, Kosiak W. Usefulness of lung ultrasound in diagnosing causes of exacerbation in patients with chronic dyspnea. [Review]. *Pneumonologia i Alergologia Polska*. 84(1):38-46, 2016.
33. Hwang HJ, Hoffman EA, Lee CH, et al. The role of dual-energy computed tomography in the assessment of pulmonary function. [Review]. *European Journal of Radiology*. 86:320-334, 2017 Jan.
34. Lynch DA, Austin JH, Hogg JC, et al. CT-Definable Subtypes of Chronic Obstructive Pulmonary Disease: A Statement of the Fleischner Society. *Radiology*. 2015;277(1):192-205.
35. Okajima Y, Come CE, Nardelli P, et al. Luminal Plugging on Chest CT Scan: Association With Lung Function, Quality of Life, and COPD Clinical Phenotypes. *Chest*. 158(1):121-130, 2020 07.
36. Diaz AA, Orejas JL, Grumley S, et al. Airway-Occluding Mucus Plugs and Mortality in Patients With Chronic Obstructive Pulmonary Disease. *JAMA*. 329(21):1832-1839, 2023 06 06.
37. Regan EA, Lynch DA, Curran-Everett D, et al. Clinical and Radiologic Disease in Smokers With Normal Spirometry. *JAMA Intern Med*. 2015;175(9):1539-1549.
38. Woodruff PG, Barr RG, Bleeker E, et al. Clinical Significance of Symptoms in Smokers with Preserved Pulmonary Function. *New England Journal of Medicine*. 374(19):1811-21, 2016 May 12.
39. Raoof S, Shah M, Make B, et al. Lung Imaging in COPD Part 1: Clinical Usefulness. [Review]. *Chest*. 164(1):69-84, 2023 07.
40. Labaki WW, Han MK. Improving Detection of Early Chronic Obstructive Pulmonary Disease. [Review]. *Annals of the American Thoracic Society*. 15(Suppl 4):S243-S248, 2018 12.
41. Kasuga I, Maezawa H, Gamo S, et al. Evaluation of chest radiography and low-dose computed tomography as valuable screening tools for thoracic diseases. *Medicine*. 101(29):e29261, 2022 Jul 22.
42. Klein JS, Gamsu G, Webb WR, Golden JA, Müller NL. High-resolution CT diagnosis of emphysema in symptomatic patients with normal chest radiographs and isolated low diffusing capacity. *Radiology*. 1992 Mar;182(3):817-21.
43. Kim SS, Seo JB, Lee HY, et al. Chronic obstructive pulmonary disease: lobe-based visual assessment of volumetric CT by Using standard images--comparison with quantitative CT and pulmonary function test in the COPDGene study. *Radiology*. 2013;266(2):626-635.
44. Boes JL, Hoff BA, Bule M, et al. Parametric response mapping monitors temporal changes on lung CT scans in the subpopulations and intermediate outcome measures in COPD Study (SPIROMICS). *Acad Radiol*. 2015;22(2):186-194.
45. Gu S, Leader J, Zheng B, et al. Direct assessment of lung function in COPD using CT densitometric measures. *Physiol Meas*. 2014;35(5):833-845.
46. Lee YK, Oh YM, Lee JH, et al. Quantitative assessment of emphysema, air trapping, and airway thickening on computed tomography. *Lung*. 2008; 186(3):157-165.

- 47.** Wang G, Wang L, Ma Z, Zhang C, Deng K. Quantitative emphysema assessment of pulmonary function impairment by computed tomography in chronic obstructive pulmonary disease. *J Comput Assist Tomogr.* 2015;39(2):171-175.
- 48.** Yahaba M, Kawata N, Iesato K, et al. The effects of emphysema on airway disease: correlations between multi-detector CT and pulmonary function tests in smokers. *Eur J Radiol.* 2014;83(6):1022-1028.
- 49.** Lee JS, Lee SM, Seo JB, et al. Clinical utility of computed tomographic lung volumes in patients with chronic obstructive pulmonary disease. *Respiration.* 2014;87(3):196-203.
- 50.** Martinez CH, Chen YH, Westgate PM, et al. Relationship between quantitative CT metrics and health status and BODE in chronic obstructive pulmonary disease. *Thorax.* 2012;67(5):399-406.
- 51.** Nambu A, Zach J, Schroeder J, et al. Quantitative computed tomography measurements to evaluate airway disease in chronic obstructive pulmonary disease: Relationship to physiological measurements, clinical index and visual assessment of airway disease. [Review]. *Eur J Radiol.* 85(11):2144-2151, 2016 Nov.
- 52.** Bodduluri S, Puliyakote ASK, Gerard SE, et al. Airway fractal dimension predicts respiratory morbidity and mortality in COPD. *Journal of Clinical Investigation.* 128(12):5374-5382, 2018 12 03.
- 53.** Han MK, Bartholmai B, Liu LX, et al. Clinical significance of radiologic characterizations in COPD. *COPD.* 2009; 6(6):459-467.
- 54.** Ostridge K, Williams NP, Kim V, et al. Relationship of CT-quantified emphysema, small airways disease and bronchial wall dimensions with physiological, inflammatory and infective measures in COPD. *Respiratory Research.* 19(1):31, 2018 02 20.
- 55.** Van Tho N, Ogawa E, Trang le TH, et al. A mixed phenotype of airway wall thickening and emphysema is associated with dyspnea and hospitalization for chronic obstructive pulmonary disease. *Ann Am Thorac Soc.* 12(7):988-96, 2015 Jul.
- 56.** Zulueta JJ, Wisnivesky JP, Henschke CI, et al. Emphysema scores predict death from COPD and lung cancer. *Chest.* 2012;141(5):1216-1223.
- 57.** Camiciottoli G, Bartolucci M, Maluccio NM, et al. Spirometrically gated high-resolution CT findings in COPD: lung attenuation vs lung function and dyspnea severity. *Chest.* 2006; 129(3):558-564.
- 58.** Capaldi DP, Zha N, Guo F, et al. Pulmonary Imaging Biomarkers of Gas Trapping and Emphysema in COPD: (3)He MR Imaging and CT Parametric Response Maps. *Radiology.* 2016;279(2):597-608.
- 59.** Ohno Y, Koyama H, Yoshikawa T, et al. Comparison of capability of dynamic O(2)-enhanced MRI and quantitative thin-section MDCT to assess COPD in smokers. *Eur J Radiol.* 2012;81(5):1068-1075.
- 60.** Zhang WJ, Hubbard Cristinacce PL, Bondesson E, et al. MR Quantitative Equilibrium Signal Mapping: A Reliable Alternative to CT in the Assessment of Emphysema in Patients with Chronic Obstructive Pulmonary Disease. *Radiology.* 2015;275(2):579-588.
- 61.** Cleverley JR, Muller NL. Advances in radiologic assessment of chronic obstructive pulmonary disease. *Clin Chest Med.* 2000;21(4):653-663.

- 62.** Wallace GM, Winter JH, Winter JE, Taylor A, Taylor TW, Cameron RC. Chest X-rays in COPD screening: are they worthwhile? *Respir Med*. 2009; 103(12):1862-1865.
- 63.** Rittayamai N, Chuaychoo B, Tscheikuna J, Dres M, Goligher EC, Brochard L. Ultrasound Evaluation of Diaphragm Force Reserve in Patients with Chronic Obstructive Pulmonary Disease. *Annals of the American Thoracic Society*. 17(10):1222-1230, 2020 10.
- 64.** Kumar R, Spalgais S, Ranga V. Hypersensitivity pneumonitis: clinical, radiological and pathological profile of 103 patients from North India. *Monaldi Archives for Chest Disease*. 90(3), 2020 Aug 03. *Monaldi Arch Chest Dis*. 90(3), 2020 Aug 03.
- 65.** Uriisman A, Jones KD. Small Airway Disease: A Step Closer to Etiology-Based Classification of Bronchiolitis. [Review]. *Surgical pathology clinics*. 13(1):189-196, 2020 Mar.
- 66.** Wang Y, Jin C, Wu CC, et al. Organizing pneumonia of COVID-19: Time-dependent evolution and outcome in CT findings. *PLoS ONE* [Electronic Resource]. 15(11):e0240347, 2020.
- 67.** Wei J, Yang H, Lei P, et al. Analysis of thin-section CT in patients with coronavirus disease (COVID-19) after hospital discharge. *Journal of X-Ray Science & Technology*. 28(3):383-389, 2020.
- 68.** Singh SJ, Baldwin MM, Daynes E, et al. Respiratory sequelae of COVID-19: pulmonary and extrapulmonary origins, and approaches to clinical care and rehabilitation. [Review]. *The Lancet Respiratory Medicine*. 11(8):709-725, 2023 08.
- 69.** Bocchino M, Rea G, Capitelli L, Lieto R, Bruzzese D. Chest CT Lung Abnormalities 1 Year after COVID-19: A Systematic Review and Meta-Analysis. *Radiology*. 308(1):e230535, 2023 07.
- 70.** Vural A, Kahraman AN. Pulmonary fibrotic-like changes on follow-up chest CT exam in patients recovering from COVID-19 pneumonia. *Tuberkuloz ve Toraks*. 69(4):492-498, 2021 Dec.
- 71.** Guler SA, Ebner L, Aubry-Beigelman C, et al. Pulmonary function and radiological features 4 months after COVID-19: first results from the national prospective observational Swiss COVID-19 lung study. *European Respiratory Journal*. 57(4), 2021 04.
- 72.** Nunez-Fernandez M, Ramos-Hernandez C, Garcia-Rio F, et al. Evolution and long-term respiratory sequelae after severe COVID-19 pneumonia: nitric oxide diffusion measurement value. *Respiratory Research*. 24(1):48, 2023 Feb 13.
- 73.** Bardakci MI, Ozturk EN, Ozkarafakili MA, Ozkurt H, Yanc U, Yildiz Sevgi D. Evaluation of long-term radiological findings, pulmonary functions, and health-related quality of life in survivors of severe COVID-19. *Journal of Medical Virology*. 93(9):5574-5581, 2021 Sep.
- 74.** Wu X, Liu X, Zhou Y, et al. 3-month, 6-month, 9-month, and 12-month respiratory outcomes in patients following COVID-19-related hospitalisation: a prospective study. *The Lancet Respiratory Medicine*. 9(7):747-754, 2021 07.
- 75.** Aul DR, Gates DJ, Draper DA, et al. Complications after discharge with COVID-19 infection and risk factors associated with development of post-COVID pulmonary fibrosis. *Respiratory Medicine*. 188:106602, 2021 11.
- 76.** Balbi M, Conti C, Imeri G, et al. Post-discharge chest CT findings and pulmonary function tests in severe COVID-19 patients. *European Journal of Radiology*. 138:109676, 2021 May.

- 77.** Van Zeller C, Anwar A, Ramos-Bascon N, Barnes N, Madden B. Pulmonary function, computerized tomography features and six-minute walk test at three months in severe COVID-19 patients treated with intravenous pulsed methylprednisolone: a preliminary report. *Monaldi Archives for Chest Disease*. 91(4), 2021 Jul 19.
- 78.** Han X, Fan Y, Alwaid O, et al. Six-month Follow-up Chest CT Findings after Severe COVID-19 Pneumonia. *Radiology*. 299(1):E177-E186, 2021 04.
- 79.** Miwa M, Nakajima M, Kaszynski RH, et al. Abnormal pulmonary function and imaging studies in critical COVID-19 survivors at 100 days after the onset of symptoms. *Respiratory Investigation*. 59(5):614-621, 2021 Sep.
- 80.** Chen L, Wang Q, Wu H, Hu J, Zhang J. Repeat Chest Ct Scans in Moderate-to-Severe Patients' Management during the Covid-19 Pandemic: Observations from a Single Centre in Wuhan, China. *Radiat Prot Dosimetry* 2020;190:269-75.
- 81.** Stylemans D, Smet J, Hanon S, et al. Evolution of lung function and chest CT 6 months after COVID-19 pneumonia: Real-life data from a Belgian University Hospital. *Respiratory Medicine*. 182:106421, 2021 06.
- 82.** Garg M, Lamicchane S, Maralakunte M, et al. Role of MRI in the Evaluation of Pulmonary Sequel Following COVID-19 Acute Respiratory Distress Syndrome (ARDS). *Current Problems in Diagnostic Radiology*. 52(2):117-124, 2023 Mar-Apr.
- 83.** Pecoraro M, Cipollari S, Marchitelli L, et al. Cross-sectional analysis of follow-up chest MRI and chest CT scans in patients previously affected by COVID-19. *Radiologia Medica*. 126(10):1273-1281, 2021 Oct.
- 84.** Eksombatchai D, Wongsin T, Phongnarudech T, Thammavaranuct K, Amornputisathaporn N, Sungkanuparph S. Pulmonary function and six-minute-walk test in patients after recovery from COVID-19: A prospective cohort study. *PLoS ONE [Electronic Resource]*. 16(9):e0257040, 2021.
- 85.** Mandal S, Barnett J, Brill SE, et al. 'Long-COVID': a cross-sectional study of persisting symptoms, biomarker and imaging abnormalities following hospitalisation for COVID-19. *Thorax*. 76(4):396-398, 2021 04.
- 86.** Altersberger M, Goliasch G, Khafaga M, et al. Echocardiography and Lung Ultrasound in Long COVID and Post-COVID Syndrome, a Review Document of the Austrian Society of Pneumology and the Austrian Society of Ultrasound in Medicine. [Review]. *Journal of Ultrasound in Medicine*. 42(2):269-277, 2023 Feb.
- 87.** Burkert J, Jarman R, Deol P. Evolution of Lung Abnormalities on Lung Ultrasound in Recovery From COVID-19 Disease-A Prospective, Longitudinal Observational Cohort Study. *Journal of Ultrasound in Medicine*. 42(1):147-159, 2023 Jan.
- 88.** Barbieri G, Gargani L, Lepri V, et al. Long-term lung ultrasound follow-up in patients after COVID-19 pneumonia hospitalization: A prospective comparative study with chest computed tomography. *European Journal of Internal Medicine*. 110:29-34, 2023 04.
- 89.** Fortini A, Torrigiani A, Sbaragli S, et al. COVID-19: persistence of symptoms and lung alterations after 3-6 months from hospital discharge. *Infection*. 49(5):1007-1015, 2021 Oct.
- 90.** Russo G, Flor N, Casella F, et al. Lung ultrasound in the follow-up of severe COVID-19 pneumonia: six months evaluation and comparison with CT. *Internal & Emergency Medicine*

Medicine. 17(8):2261-2268, 2022 11.

91. Halifax RJ, Haris M, Corcoran JP, et al. Role of CT in assessing pleural malignancy prior to thoracoscopy. *Thorax*. 2015;70(2):192-193.
92. Tsujimoto N, Saraya T, Light RW, et al. A Simple Method for Differentiating Complicated Parapneumonic Effusion/Empyema from Parapneumonic Effusion Using the Split Pleura Sign and the Amount of Pleural Effusion on Thoracic CT. *PLoS ONE*. 10(6):e0130141, 2015.
93. Kuhlman JE, Singha NK. Complex disease of the pleural space: radiographic and CT evaluation. *Radiographics*. 1997;17(1):63-79.
94. McLoud TC, Flower CD. Imaging the pleura: sonography, CT, and MR imaging. *AJR Am J Roentgenol*. 1991;156(6):1145-1153.
95. Inan N, Sarisoy HT, Cam I, Sakci Z, Arslan A. Diffusion-weighted Magnetic Resonance Imaging in the Differential Diagnosis of Benign and Metastatic Malignant Pleural Thickening. *J Thorac Imaging*. 2016;31(1):37-42.
96. Rinaldi P, Parapatt GK, Giuliani M, et al. Chest and breast MRI: the added value of a fast imaging for a new diagnostic approach in the planning of augmentation surgery in patients with thoracic asymmetries. *Eur Rev Med Pharmacol Sci*. 2015;19(13):2359-2367.
97. Blackmore CC, Black WC, Dallas RV, Crow HC. Pleural fluid volume estimation: a chest radiograph prediction rule. *Acad Radiol*. 1996;3(2):103-109.
98. Svigals PZ, Chopra A, Ravenel JG, Nietert PJ, Huggins JT. The accuracy of pleural ultrasonography in diagnosing complicated parapneumonic pleural effusions. *Thorax*. 72(1):94-95, 2017 01. *Thorax*. 72(1):94-95, 2017 01.
99. Tsai T-H, Jerng J-S, Yang P-C. Clinical Applications of Transthoracic Ultrasound in Chest Medicine. *Journal of Medical Ultrasound* 2008;16:7-25.
100. Sukkasem W, Moftah SG, Kicska G, Godwin JD, Pipavath S, Stern E. Crus Atrophy: Accuracy of Computed Tomography in Diagnosis of Diaphragmatic Paralysis. *J Thorac Imaging*. 2017 Nov;32(6):383-390.
101. Nason LK, Walker CM, McNeeley MF, Burivong W, Fligner CL, Godwin JD. Imaging of the diaphragm: anatomy and function. [Review]. *Radiographics*. 32(2):E51-70, 2012 Mar-Apr. *Radiographics*. 32(2):E51-70, 2012 Mar-Apr.
102. Saltiel RV, Grams ST, Pedrini A, Paulin E. High reliability of measure of diaphragmatic mobility by radiographic method in healthy individuals. *Braz J Phys Ther*. 2013;17(2):128-136.
103. Chen Y, Li P, Wang J, Wu W, Liu X. Assessments and Targeted Rehabilitation Therapies for Diaphragmatic Dysfunction in Patients with Chronic Obstructive Pulmonary Disease: A Narrative Review. [Review]. *International Journal of Copd*. 17:457-473, 2022. *Int J Chron Obstruct Pulmon Dis*. 17:457-473, 2022.
104. Kiryu S, Loring SH, Mori Y, Rofsky NM, Hatabu H, Takahashi M. Quantitative analysis of the velocity and synchronicity of diaphragmatic motion: dynamic MRI in different postures. *Magn Reson Imaging*. 24(10):1325-32, 2006 Dec.
105. Mogalle K, Perez-Rovira A, Ciet P, et al. Quantification of Diaphragm Mechanics in Pompe Disease Using Dynamic 3D MRI. *PLoS ONE* [Electronic Resource]. 11(7):e0158912, 2016. *PLoS ONE*. 11(7):e0158912, 2016.

- 106.** Verhey PT, Gosselin MV, Primack SL, Kraemer AC. Differentiating diaphragmatic paralysis and eventration. *Acad Radiol.* 2007;14(4):420-425.
- 107.** Noh DK, Lee JJ, You JH. Diaphragm breathing movement measurement using ultrasound and radiographic imaging: a concurrent validity. *Bio-Medical Materials & Engineering.* 24(1):947-52, 2014. *Biomed Mater Eng.* 24(1):947-52, 2014.
- 108.** Sarwal A, Walker FO, Cartwright MS. Neuromuscular ultrasound for evaluation of the diaphragm. *Muscle Nerve.* 2013;47(3):319-329.
- 109.** Boon AJ, Sekiguchi H, Harper CJ, et al. Sensitivity and specificity of diagnostic ultrasound in the diagnosis of phrenic neuropathy. *Neurology.* 83(14):1264-70, 2014 Sep 30. *Neurology.* 83(14):1264-70, 2014 Sep 30.
- 110.** Fantini R, Mandrioli J, Zona S, et al. Ultrasound assessment of diaphragmatic function in patients with amyotrophic lateral sclerosis. *Respirology.* 2016;21(5):932-938.
- 111.** Hiwatani Y, Sakata M, Miwa H. Ultrasonography of the diaphragm in amyotrophic lateral sclerosis: clinical significance in assessment of respiratory functions. *Amyotroph Lateral Scler Frontotemporal Degener.* 2013;14(2):127-131.
- 112.** O'Gorman CM, O'Brien T G, Boon AJ. Utility Of diaphragm ultrasound in myopathy. *Muscle Nerve.* 2017;55(3):427-429.
- 113.** Baria MR, Shahgholi L, Sorenson EJ, et al. B-mode ultrasound assessment of diaphragm structure and function in patients with COPD. *Chest.* 2014;146(3):680-685.
- 114.** Carrie C, Bonnarde E, Vally R, Revel P, Marthan R. Vital Capacity Impairment due to Neuromuscular Disease and its Correlation with Diaphragmatic Ultrasound: A Preliminary Study. *Ultrasound Med Biol.* 2016;42(1):143-149.
- 115.** Noda Y, Sekiguchi K, Kohara N, Kanda F, Toda T. Ultrasonographic diaphragm thickness correlates with compound muscle action potential amplitude and forced vital capacity. *Muscle & Nerve.* 53(4):522-7, 2016 Apr. *Muscle Nerve.* 53(4):522-7, 2016 Apr.
- 116.** Pinto S, Alves P, Pimentel B, Swash M, de Carvalho M. Ultrasound for assessment of diaphragm in ALS. *Clinical Neurophysiology.* 127(1):892-897, 2016 Jan. *Clin Neurophysiol.* 127(1):892-897, 2016 Jan.
- 117.** Santana PV, Prina E, Albuquerque AL, Carvalho CR, Caruso P. Identifying decreased diaphragmatic mobility and diaphragm thickening in interstitial lung disease: the utility of ultrasound imaging. *Jornal Brasileiro De Pneumologia: Publicacao Oficial Da Sociedade Brasileira De Pneumologia E Tisiologia.* 42(2):88-94, 2016 Apr. *J Bras Pneumol.* 42(2):88-94, 2016 Apr.
- 118.** Measuring Sex, Gender Identity, and Sexual Orientation.
- 119.** American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://edge.sitecorecloud.io/americanoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf>.

## Disclaimer

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.

<sup>a</sup>Duke University Medical Center, Durham, North Carolina. <sup>b</sup>Research Author, Duke Health, Durham, North Carolina. <sup>c</sup>Panel Chair, University of Kansas Medical Center, Kansas City, Kansas. <sup>d</sup>Panel Vice-Chair, Mayo Clinic Florida, Jacksonville, Florida. <sup>e</sup>UT Southwestern Medical Center, Dallas, Texas. <sup>f</sup>Portland VA Healthcare System and Oregon Health & Science University, Portland, Oregon. <sup>g</sup>University of Kansas Health System, Kansas City, Kansas. <sup>h</sup>The University of Chicago Medicine, Chicago, Illinois. <sup>i</sup>Creighton University School of Medicine, Omaha, Nebraska. <sup>j</sup>University of North Carolina at Chapel Hill, Chapel Hill, North Carolina; American Thoracic Society. <sup>k</sup>Rush University Medical Center, Chicago, Illinois; The Society of Thoracic Surgeons. <sup>l</sup>The Warren Alpert Medical School of Brown University and Rhode Island Medical Imaging, Providence, Rhode Island; Commission on Nuclear Medicine and Molecular Imaging. <sup>m</sup>Brigham & Women's Hospital, Boston, Massachusetts. <sup>n</sup>University of Massachusetts Memorial Medical Center, Worcester, Massachusetts; American College of Physicians. <sup>o</sup>The University of Texas MD Anderson Cancer Center, Houston, Texas. <sup>p</sup>University of Calgary, Calgary, Alberta, Canada; American College of Chest Physicians. <sup>q</sup>Emory University, Atlanta, Georgia; Society of General Internal Medicine. <sup>r</sup>Specialty Chair, University of Chicago, Chicago, Illinois.