William L. Eschenbacher, MD

5 Radiology: Use of Lung Imaging to Help in the Identification of Patients with COPD

Key Points
1. Radiographic imaging can be complementary to lung function testing in the identification of patients with COPD.
2. Chest radiographs are useful as part of the initial evaluation of patients with respiratory symptoms but CT scans especially high-resolution CT scans (HRCT) can provide more information for the evaluation of the presence of emphysema, air-trapping, or smoking-related interstitial lung diseases.
3. PET Scans can discriminate malignant vs. benign lesions in patients with smoking histories who are found to have lung nodules by chest radiographs or CT scans.
4. Newer imaging techniques using MRI scans are being evaluated in research settings for functional analysis of smaller airways including airway wall size and distribution of air flow in patients with COPD.

5.1 Introduction

The use of radiographic imaging of the lungs is complementary to the use of lung function testing in the identification of patients with COPD. As part of the initial evaluation of patients who present with respiratory symptoms (dyspnea, cough, sputum production, chest tightness, wheezing, etc.), a routine chest radiograph is usually obtained. For most patients with COPD, this may be the only imaging study that is needed. For further evaluation of the presence and severity of the changes seen in patients with COPD, CT imaging can also be performed. This more advanced imaging is useful if abnormalities are identified by the chest radiograph or if other conditions related to smoking are being considered in the evaluation of the patient’s symptoms. Other advanced imaging techniques such as PET scanning or MRI scanning have some utility in COPD but are limited by cost and technical capabilities. However, ongoing research in these areas may ultimately provide a better understanding of relationships between distribution of ventilation and structure-function in patients with all severities of COPD including better estimation of disease progression and response to therapy (Coxson, 2014).

5.2 Chest Radiographs

Routine posterior-anterior (PA) and lateral views of the chest are standard images that can be ordered for patients who present with respiratory symptoms that may
represent COPD. Besides identifying features of the lung that can be seen with COPD, the routine chest radiograph can be helpful to exclude other conditions such as lung cancer, heart failure and pneumonia.

Features of COPD that can be seen on routine posterior-anterior (PA) and lateral chest radiographs include 1) hyperinflation as noted by flattening of the diaphragms (especially noted on the lateral view) and increase in the retrosternal airspace (also seen on the lateral view) along with widening of the costophrenic angles (on the PA view), 2) presence of bullae that can be detected on standard images, and 3) tapering and reduction of the number of pulmonary vessels especially as they are seen in the lung periphery. An example of a standard chest radiograph for a patient with COPD is seen in Figure 5.1.

Other conditions that may be identified by chest radiographs in patients with COPD that present with acute symptoms include pleural effusions and pneumonia. Other smoking-related lung diseases (such as smoking-related interstitial lung diseases) may be suggested by chest radiographs but in most instances, further evaluation with more advanced imaging including CT scans is indicated.

5.3 Computed Tomography (CT) Scans

5.3.1 CT Scans and Emphysema

The value of CT scans in the further evaluation of patients with COPD has been well documented (Webb, 2009). This is especially true for the identification of the presence of emphysema (one of the two elements of COPD along with the clinical definition of
chronic bronchitis) (Friedman, 2008; Takahashi, 2008). Emphysematous regions of the lung are defined as those areas that are 2 standard deviations below normal lung parenchymal density (-750 to -850 Hounsfield Units (HU)) with a threshold value of -900 to -910 HU. In some studies, a threshold value of -950 HU is used. The presence and extent of emphysema can then be categorized as: 1) less than 25% of the area, 2) 26 to 50% of the area, 3) 51 to 75% of the area or 4) 76 to 100% of the area examined.

Of the different forms of CT imaging, HRCT is the most sensitive method for identifying emphysematous changes. An example of emphysematous changes on a HRCT is shown in Figure 5.2.

5.3.2 CT Scans and Air-trapping

Air-trapping is a pathophysiological term indicating the retention of excess gas in all or part of the lungs at any stage of expiration. Air-trapping is a finding characteristic of obstruction of the airways and is found in all forms of obstructive lung diseases including asthma and COPD. There may be other associated pathological conditions associated with air-trapping including bronchiectasis (which also may be seen in a phenotype of COPD: see below) and interstitial lung disease (Miller, 2014).

Figure 5.2: High-resolution CT scan imaging of a patient with severe emphysema. A hallmark of emphysema on high resolution CT scan imaging is the paucity of parenchymal and vascular markings that is often referred to as “holes without walls.”
In pulmonary function testing, air-trapping is the increase in residual volume (RV) or RV/TLC measurement compared to the predicted value. Radiographically, air-trapping is noted with CT scans with inspiratory and expiratory phases of imaging with the expiratory phase compared to the inspiratory images showing patchy areas of decreased lung attenuation consistent with air that has not been exhaled (Stern, 1994; Matsuoka, 2008). The Fleischner Society defines air-trapping as “parenchymal areas with less than normal increase in attenuation and lack of volume reduction” as seen on end-expiration CT scans” (Hansell, 2008). An example of the presence of air-trapping seen with an expiratory phase of a CT scan is shown in Figure 5.3.

5.3.3 CT Evaluation of Airway Changes in COPD

In addition to identifying the presence of emphysema, CT scans can identify other characteristics of COPD including airway luminal and airway wall changes that are characteristic of chronic bronchitis and bronchiectasis.
More recent techniques using CT scans have been able to measure airway luminal internal diameter and airway wall thickness in patients with COPD (Nakano, 2005; Patel, 2008). These methods require quantitative measurements of cross-sectional airway dimensions using transverse CT images (Lutey, 2013). Airways less than 2–3 mm in diameter are thought to be the location where the greatest changes occur for patients with COPD and the major site of airflow obstruction. Algorithms have been developed to take into consideration the oblique sectioning of airways on transverse images to arrive at better estimates of luminal diameter and airway wall thickness for these smaller airways. Further studies have shown good correlations between the airway changes and respiratory symptoms (Grydeland, 2010). In addition newer studies using MRI imaging with hyperpolarized helium-3 (He³) demonstrate regional gas distribution changes that correlate with the CT findings of the changes in these smaller airways (see later discussion regarding MRI imaging).

5.3.4 CT Scans for COPD Phenotypes

COPD might be best described by different phenotypes of presentation and illness (Vestbo, 2014). For example, there are the phenotypes of the frequent exacerbator (two or more exacerbations in the previous year), the overlap COPD-asthma phenotype, the emphysema-hyperinflation phenotype, and the bronchiectasis phenotype (Miravitlles, 2012; Martinez-Garcia, 2011). Several of these phenotypes are best described using CT scan results such as the emphysema and bronchiectasis phenotype presentations (Shah, 2014). The identification of bronchiectasis by CT scan has been defined previously by Naidich et al: air-fluid levels in distended bronchi, a linear array or cluster of cysts, dilated bronchi in the periphery of the lung and bronchial wall thickening due to peribronchial fibrosis (Naidich, 1982). An example of bronchiectasis as noted by CT scan is shown in Figure 5.4.

5.3.5 Lack of Correlation Between CT Findings and Spirometric Results for COPD

COPD is composed of two separate conditions: emphysema and airways disease represented by chronic bronchitis. Most patients with COPD will have some combination of these two pathological processes. The hallmark of airflow limitation in COPD is reduced maximal expiratory flow rates measured by spirometry. The pathological changes in the lungs that result in the reduced expiratory flow rates are 1) increased flow resistive properties of the airways (as in chronic bronchitis) and 2) reduced elastic recoil of the lung (as in emphysema). In COPD, the airways can be narrowed as a result of inflammatory changes and smooth muscle hypertrophy in the airway wall and increased amount of mucous and inflammatory material within the airway lumen. There is increased resistance to airflow as a result of the narrowed airway leading to
reduced flow rates for the same driving pressure that is generated to cause expiratory flow. In addition, loss of parenchymal tissue with emphysematous changes can reduce the support of airway walls contributing to airway narrowing and increased airway resistance. Also, the emphysematous changes reduce the elastic recoil and in turn the pressure gradient that is in part responsible for the generation of the expiratory flow rates.

However, recent studies suggest that the presence of airflow limitation noted by spirometry may not correlate well with the anatomic presence of emphysematous changes as noted on CT scans. In an editorial referring to this disconnect, Dr. James Hogg (Hogg, 2012) noted that the pathological process that leads to emphysema “in which the destructive process rapidly extends along surviving distal conducting airways to initiate emphysematous destruction of the alveolar surface...can account for the appearance of emphysema before a sufficient number of small airways have been destroyed to cause a reduction in FEV1.”

5.3.6 CT Scans for Smoking-related Interstitial Lung Diseases

As mentioned above, CT scans are also useful when there may be other smoking-related changes in the lungs. These other abnormalities can include smoking-related interstitial lung disease (ILD) and lung cancer.
An example of the usefulness of CT scans in identifying the presence of smoking-related ILD is the finding of Smoking-related Respiratory Bronchiolitis with Fibrosis as described by Reddy and Churg (Reddy, 2013). They described a CT pattern of patchy areas of reticular changes about upper zone emphysematous spaces in individuals who do not have evidence of a diffuse ILD.

Other smoking related ILDs that have been defined using CT scan findings include Desquamative Interstitial Pneumonia (DIP), Respiratory Bronchiolitis-Interstitial Lung Disease (RB-ILD), Pulmonary Langerhans Cell Histiocytosis (PLCH) and even Idiopathic Pulmonary Fibrosis (IPF) which may occur more frequently in current and former smokers (Webb, 2009).

5.3.7 Use of Low Dose CT Scans for Surveillance for Lung Cancer

As also mentioned, CT scans can be used for the identification of other lung abnormalities in smokers especially the finding of bronchogenic carcinoma. The U.S. Preventive Services Task Force (among other professional societies) has recommended annual screening for lung cancer with low-dose CT scans in adults ages 55 to 80 years who have a 30 pack-year smoking history and who currently smoke or have quit within the past 15 years (Moyer, 2014).

5.4 Other Advanced Imaging Techniques in COPD

5.4.1 PET Scans

Positive emission tomography or PET scan is an imaging technique that examines the metabolic activity of lesions throughout the body that have been identified by other imaging techniques. A radiotracer such as fluorodeoxyglucose (FDG) that contains both sugar and radioactive elements is injected into the individual who is then scanned to detect those areas that have taken up and metabolized the sugar moiety and are radioactive. PET scans can differentiate malignant lesions (which are highly metabolically active) and benign lesions such as scars or fibrotic areas that are not active. If the lesion is an inflammatory process such as an active infection, it may also take up the radiotracer and be PET scan positive. The role of PET scanning in COPD is mostly for those patients who have a smoking history and have had nodules or other abnormalities identified by routine chest radiographs or CT scans. The PET scan can then be helpful in discriminating a malignant lesion from a benign lesion in these patients.
5.4.2 MRI Scans

1. As mentioned above in the section on CT Evaluation of Airway Changes in COPD, there are newer imaging techniques being evaluated in research settings using magnetic resonance imaging (MRI) scanning. Helium-3 (He3) and xenon-129 (Xe129) are gaseous magnetic resonance (MR) contrast agents that can be inhaled, permitting visualization of lung airspaces in an MR image (Salerno, 2001; Moller, 2002; van Beek, 2004). The MR signal from these hyperpolarized gases is easily detected using an MR scanner tuned to the appropriate resonance frequency.

2. MRI of hyperpolarized gases has led to the development of unique strategies for evaluating the structure and function of the lung (Salerno, 2001; Moller, 2002; van Beek, 2004). In particular, the relatively high solubility of xenon in biological tissues (Abraham, 1985), and an exquisite sensitivity to its environment that results in an enormous range (~200 ppm) of chemical shifts upon solution (Miller, 1981), make hypXe129 particularly attractive for exploring certain characteristics of lung function, such as gas exchange and uptake (Sakai, 1996). The quantitative characteristics of exchange and uptake are determined by physiologic parameters, including the surface-to-volume ratio and the thickness of the blood-gas barrier (Driehuys, 2006).

3. Since the primary function of the lung is gas exchange, impaired gas transport or exchange in subjects with pulmonary disease such as COPD can cause symptomatic shortness of breath. Non-equilibrium xenon uptake spectroscopy (NEXUS) can quantify the gas transport from the major airways all the way down to the alveolar gas exchange sites with high temporal resolution. In addition, chemical shift saturation recovery (CSSR) MR spectroscopy can be employed to measure the alveolar septal wall thickness and surface-to-volume ratio, both potentially highly relevant physiological parameters for the characterization of lung function in these patients with obstructive airways disease.

5.5 Summary Points

1. To better understand the pathophysiology of COPD including the impact of the disease for the patient and response to therapy requires more information than lung function test results. This additional information can be obtained with currently available imaging technology and other techniques now being developed.

2. Screening chest radiographs have limited usefulness but more advanced techniques such as CT scans (and in the future MRI scanning using polarized gases) can provide more helpful information including insight into the development and progression of COPD. Also, newer imaging techniques may inform us about the patient’s response to therapy that cannot be measured by standard pulmonary function testing.
References


