Imaging in chronic obstructive pulmonary disease

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Abstract

Chronic obstructive pulmonary disease is defined by irreversible airflow obstruction due to emphysematous destruction of the lung parenchyma and small airways remodeling. It is a heterogeneous disease affecting the airways and/or the parenchyma with different severity during the course of the disease. Obstructive lung diseases may be associated with a variety of pathologic findings, including emphysema, large and small airways abnormalities. Computed tomography has become the standard modality to objectively visualize lung disease. High resolution computed tomography (HRCT) can reveal morphologic abnormalities associated with obstructive lung disease with a greater accuracy than plain radiographs. HRCT is more sensitive than radiographs in showing emphysema, large airways abnormalities such as bronchiectasis, small airways abnormalities, such as bronchiolectasis and the tree-in-bud appearance, and abnormal ventilation including mosaic perfusion. This review will discuss imaging of the chest in patients with pulmonary emphysema. Definitions of types of emphysema within the framework of chronic obstructive pulmonary disease are given. The classic findings on the chest radiograph are described, and the advances in sensitivity and specificity achieved with computed tomography scanning are noted.

Keywords: *Pulmonary disease, chronic obstructive; Radiography; Thoracic; Tomography; Pulmonary emphysema.*

Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by airflow limitation. From a pathogenic point of view, it is considered to involve chronic inflammation, destruction of the pulmonary parenchyma, and narrowing of

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the small airways. These changes occur at the same time and the predominance of one above other pathological changes is determined by different features of COPD. Currently, there is a tendency to establish clinical phenotypes of COPD for better control and approaches to treatment. It is possible to establish these phenotypes on the basis of imaging results. In this way, a predominance of destructive parenchymal changes is referred to as emphysema and changes in the small airways are referred to as chronic bronchitis. The diagnosis of COPD is based on clinical and radiological data, as well as functional respiratory and pathological anatomical changes.[1-4]

COPD is a pathology with a cosmopolitan distribution, since its main causal factor is the widespread habit of tobacco smoking,[1] which is performed by most societies worldwide. The clinical course of COPD is variable, with the spectrum ranging from minimal impact to limitation of daily activities and chronic respiratory failure requiring home oxygen therapy.[5]

Currently, COPD is the fourth most common cause of death in the world[1] and contributes significantly to respiratory diseases, which are the fourth most common cause of mortality in Brazil.[3] In this review, we describe the radiological changes related to COPD and its main complications, considering the following 4 morphological types of emphysema.[6]

- Centroacinar or centrolobular: involves dilation or destruction of the respiratory bronchioles. This type of emphysema is associated with the habit of smoking in most cases and predominates in the upper lobes.
- Panacinar or panlobular: related to α1-antitrypsin deficiency, which causes dilation and complete destruction of the acini. This type of emphysema predominates in the base of the lung.
- Paraseptal: occurs on the periphery of the lung, in the pleura, or interlobularly. This type of emphysema is most commonly associated with spontaneous pneumothorax in young people and usually occurs simultaneously with the subtypes described above.
- Scar: occurs in areas of lung scarring, without preferential location. In Brazil, this type of emphysema is often found in patients with tuberculosis. It is typically limited in its extent and significance.

Correlation of clinical, radiological and functional criteria with diagnosis of COPD

Multiple clinical presentations are compatible with a diagnosis of COPD, especially if we take into account the variation of severity resulting from the duration of the illness and the degree of exposure to current or previous risk factors. Thus, it was necessary to establish at least one criterion that was present in most patients who share a diagnosis of COPD.[4] Among all the possible manifestations of COPD, the spirometry finding of fixed airway obstruction is usually present independently of any other existing variable. The presence of a Tiffeneau index of less than 70% predicted in any age group and both sexes that is not fully reversible after bronchodilator inhalation in a patient exposed to any risk factor associated with COPD is thought to be a reasonable set of criteria for confirmation of the COPD diagnosis. Clinical criteria are important, but can also be non-specific, reproducible, and subjective, with interpersonal discrepancy and dependence on functional and radiological disease severity. For example, the same degree of airway obstruction can be related to different sensations of dyspnea.[2,7]

In general, radiological findings are manifestations of the natural history of COPD and are not always associated with functional changes. Changes interpreted as devastating upon chest computed tomography (CT) may be present in asymptomatic patients, in the same way that symptomatic patients do not always exhibit prominent radiographic changes.[4]

Simple radiography in COPD

Conventional chest radiography is usually one of the first examinations requested in the evaluation of a patient with complaints and exposure history compatible with COPD. However, few morphological changes are detected in the early stages with this method.[8]

With progression of the disease, conventional radiography can be used to detect some changes with reasonable sensitivity and low specificity. The presence of overinflated lungs constitutes one of these findings, although this can be present in other situations (figure 1). Previous studies have correlated objective measurement of lung size on chest radiographs with lung function, indicating good positive predictive values, reproducibility, and reliability. Another relatively common and similarly nonspecific finding in conventional radiography is flattening and straightening of the diaphragmatic dome. The same group that studied and described the measurement of lung size as a predictor of obstructive disease found similar results with respect to certain degrees of flattening of the diaphragm and airflow limitation. These changes are more specific in the diaphragmatic radiographic diagnosis of COPD and also have prognostic value as they indicate reversal of the main muscle of respiration. Increased anteroposterior diameter and retrosternal space are other manifestations associated with increased pulmonary volume.[9]

Vascular changes can also be seen in patients with COPD, representing radiological expression of the destruction of the alveolar septum that is involved in the genesis of pulmonary emphysema. Identification of a deficiency in blood volume (oligemia) is not a pathognomonic sign of illness with fixed airway obstruction, since it can be present in other situations such as pulmonary arterial hypertension and pulmonary thromboembolism.[6]

Another radiological presentation substantially associated with COPD is the formation of

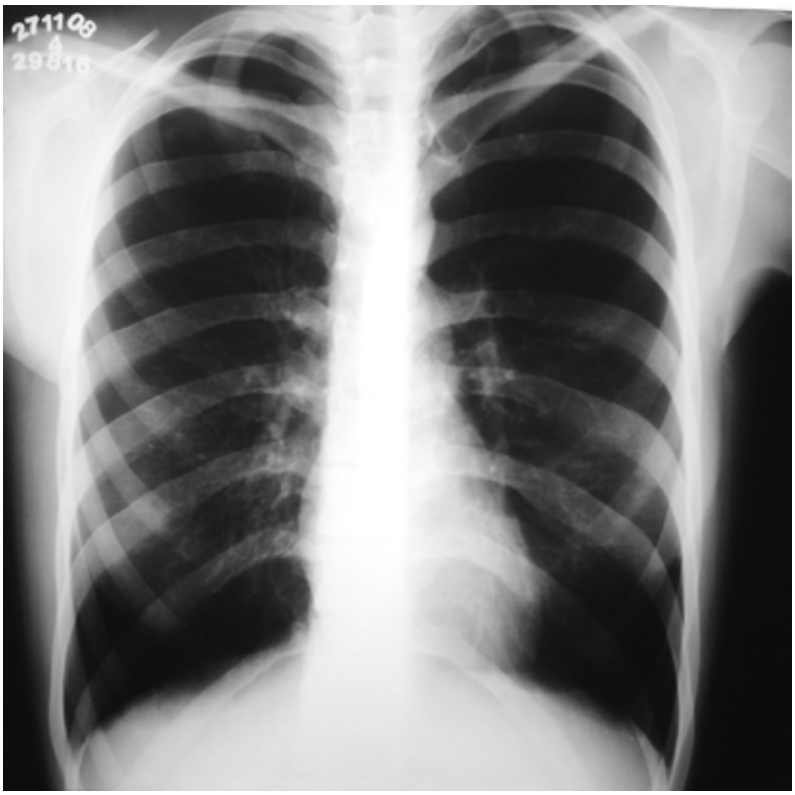


Figure 1: PA chest radiograph showing marked signs of lung hyperinflation.

lung bullae, which are islands of nonvascularized tissue devoid of functioning lung parenchyma. Lung bullae are responsible for worsening respiratory function attributed to compression of adjacent preserved tissue and can potentially cause pneumothorax, a prevalent complication in the context of bullous disease. Despite the clear association between bullae formation and emphysema, other diseases may also present the same manifestation.[10]

Radiographic changes found in chronic bronchitis are often described as thickening of the sheath, although it is sometimes difficult to detect bronchovascular changes.[4]

Computed tomography in COPD

The application of CT techniques has revolutionized imaging of the thorax as a whole. Changes only suggested by conventional radiography are seen directly and clearly when using CT. Emphysema is easily distinguishable from normal parenchyma on CT, as its attenuation value is low when compared to adjacent tissue. As mentioned earlier, there are 4 types of emphysema—panacinar, centrolobular, paraseptal, and scar—each with distinct presentations and anatomical distributions on CT images.[4]

Centrolobular emphysema is characteristic of smokers, is normally located in the lung apices, and appears as multiple small rounded areas that are not limited by walls, unlike cysts (figure 2).

Panacinar emphysema is normally located in the lower portions of the lungs and is characterized by homogeneous destruction of the side lobes, generating images with low attenuation continuously distributed by parenchyma bands. It is typical of patients with α1-antitrypsin deficiency (figure 3).

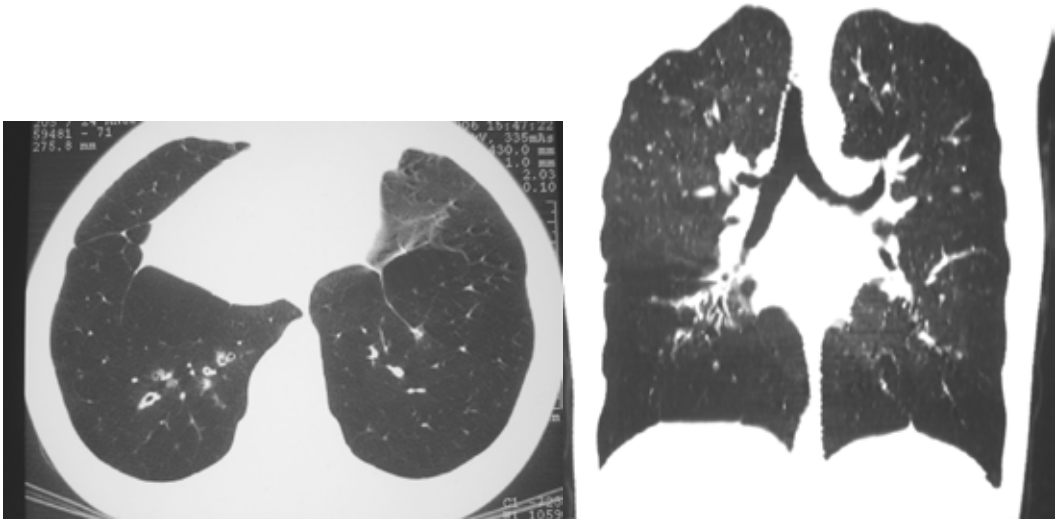
Paraseptal emphysema occupies more peripheral areas of the lung parenchyma, presenting as bullous formations near the pleura or interlobularly. It is usually associated with other types of emphysema (figure 4).

The scar emphysema subtype has little relevance in the context of obstructive disease, since it is a result of destructive and fibrotic lung processes secondary to previous damage and its functional manifestation is constraint.

The development of new techniques, in addition to improvement of previously used methods, has brought a new perspective to the tomographic evaluation of emphysema. High resolution computed tomography (HRCT), which allows sections of up to 1 mm, has enhanced viewing and made accurate quantification of more advanced pathology possible, even with subjective and examiner dependent evaluation. The diagnosis of emphysema in the incipient phase can be enhanced by the technique of minimum-intensity projection. This technique uses software capable of identifying areas of the lung parenchyma with low attenuation and simultaneously suppressing normal pulmonary parenchyma and pulmonary vessels, making it more sensitive for the detection of emphysema.[11]

The quantitative mode of CT has improved the quantification of emphysematous disease. Tomographic density is based on the measurement of Hounsfield units (HU). The quantification of lung tissue with a lower attenuation coefficient than a particular reference value considered compatible with areas of emphysema (e.g., -910 HU) can be easily established. From the acquisition of such data, a histogram of the distribution of these densities can be created and the analysis of such a graph provides tangible information allowing classification of emphysema as mild, moderate, or severe. Another possibility is the use of this technique for quantification of air trapping, a parameter that shows greater correlation with clinical deterioration and severity of disease than the amount of emphysema itself. Some previous studies were able to confirm a significant correlation between the information obtained by tomographic density and pathological findings. This interesting discovery has led experts to continue looking for simple methods of quantification that are potentially applicable to everyday clinical practice.[8,10-12]

The recent development of spiral CT



A B

Figure 2: A- Chest tomography in axial cut showing areas of panlobular emphysema in predominately lower lobes. Note cilindrics bronchiectasias and thickening of bronchical walls, most evidence in right. B- coronal reformatated showing hyperinsuflation areas in lower lobes.

Figure 3: CT slice at the level of the upper lobes demonstrating numerous areas of centrilobular emphysema.

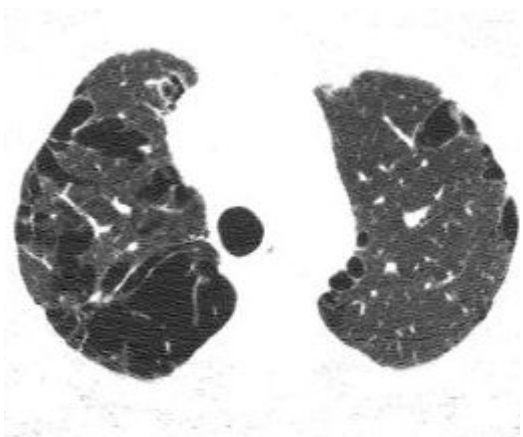


Figure 4: CT slice at the level of the upper lobes showing peripheral areas of emphysema paraseptal.

scanners with multiple detectors allows the acquisition of a full chest image in just 1 deep inspiration. This technology enables the three-dimensional reconstruction of lung images, lung volume measurements, as well as assessment of parenchymal changes and their rate of progression. Measurement of the volume of emphysema can be established through use of equation dividing the lung volume by the normal density. This allows establishment of the rate of emphysema development. Some authors point out that CT is a safe method for assessing the rate of progression of emphysema, given that it is relevant during clinical follow-up and has excellent correlation with functional tests. Studies have compared lung volume measurement by CT and plethysmography, observing significant correlation between the 2 techniques, but with an underestimated total lung capacity measured by tomography. This was probably due to the patient being placed in a supine position in the CT scanner compared to the sitting position used for plethysmography. Although few studies have been conducted in this area, it is possible to predict that in the near future lung volume measurement by CT will be embedded in clinical practice, becoming even more useful for the diagnosis, severity assessment, and

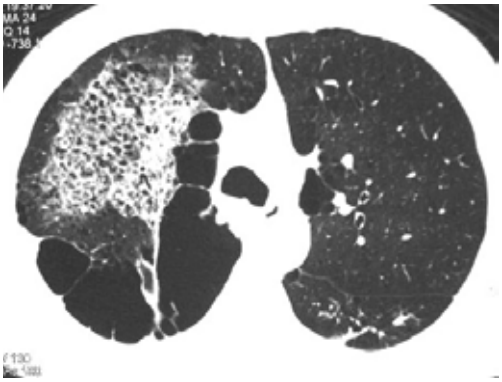


Figure 5: CT section at the level of the carina showing opacity looking "speckled" due to the substrate emphysema.

Figure 6: Coronal reformat demonstrating heterogeneous opacity in the right upper lobe and areas of centrilobular emphysema and paraseptal. Tuberculosis in COPD.

follow-up of patients with COPD.[4,12]

Major complications of COPD

Radiological assessment is particularly useful for the possible complications of COPD.[13] In relation to infectious processes potentially linked to COPD, we must remember that community-acquired pneumonia is often the cause of differences in basic pathology, which is a common occurrence in this population. In general, evaluation by simple thoracic radiograph is sufficient, and should be used when diagnostic tomography is in doubt or for better defining the extent of the illness. Consolidation can have a multifocal or lobar distribution. The radiographic pattern in patients with COPD is not always similar to the parenchymal destruction observed in basic disease, with some modification of the classic picture expected, e.g., fog aspect opacities on an irregular pathological substrate (figure 5). Viral infections may lead to a form of presentation or reticular aspect characterized as bronchovascular network enhancement, especially in bronchitic patients.[4]

Tuberculosis must also be considered as a differential diagnosis in this population, especially since the misuse of systemic corticosteroids is creating potentially immunosuppressed patients and consequently increasing the likelihood of reinfection/reactivation of this disease. The radiographic findings of tuberculosis are nonspecific and often present as heterogeneous consolidations, pleural effusion, and areas of excavation with no nodular lipid infiltrate. Location in the apical and posterior segments of the upper lobes and the superior segment of the lower lobes is most common. CT changes described as having a budding tree appearance are not always present, while this anatomical change is often associated with COPD (figure 6).[12] Histoplasmosis, a fungal disease, is also relevant in patients with emphysema. In this context, we should remember the chronic infectious conditions in presentation, it won't affect this group of patients so preferred. The main radiological finding is the presence of opacities with digging areas and this allows the differential diagnosis of pulmonary tuberculosis.[4]

Pneumothorax is a mechanical complication of COPD. It occurs mainly in patients with advanced disease, as well as in patients with pulmonary and paraseptal emphysema. It can be identified using conventional radiography as a thin pleural line limited to parenchymal structures with hyperlucent areas in contact with the chest wall. CT can be used in ambiguous cases for better assessment of the size of the pneumothorax and satisfactory placement of

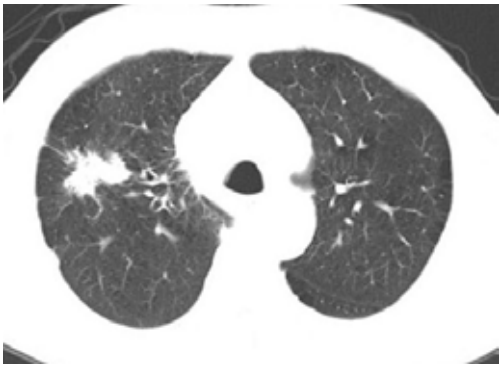


Figure 7: CT section at the level of the upper lobes showing centrilobular emphysema and areas of nodular parenchymal opacities, irregular boundaries. Lung tumor in patients with COPD.

thoracic drains.

In addition to COPD, lung tumors are directly related to smoking, and there is a large overlap between the occurrence of fixed airway obstruction and lung cancer. Upon conventional chest radiography, manifestations compatible with tumors include nodules, masses, atelectasis secondary to endobronchial lesions, mediastinal masses, diffuse interstitial disease, and pleural effusion. The advent of CT was of fundamental importance for the differential diagnosis of the lesions observed in conventional radiography, making it possible to complete diagnostic investigation without the need for surgical intervention (figure 7). The association between CT and CT with emission tomography (PET-CT) using glucose marked with a radionuclide, known as, allowed integration of the assessment of images suggestive of cancer with metabolic cellular profile and glucose uptake data. The analysis of these 2 variables assists in the differential diagnosis of lesions suggestive of neoplasm in many cases, especially in solitary nodules, which usually constitute real challenges in daily clinical practice.[14]

Cardiovascular alterations can also occur secondary to COPD. For example, increased pulmonary arterial pressure over a period of years causes right ventricular dysfunction, which is known as cor pulmonale. Signs of right ventricular overload can be seen in conventional radiography, including an increase in heart area. Pulmonary arterial hypertension is also suspected with the finding of accentuation of the arc of the pulmonary artery and peripheral vascular marks mitigation.[4]

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