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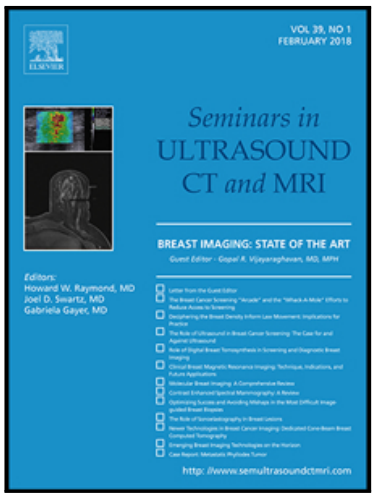


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# Occupational Lung Diseases: Underreported Diagnosis in Radiological Practice

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**Abstract**

Underreporting of occupational lung disease is a widespread problem in clinical practice. In Europe there is not a common regulation even for the recognition of occupational cancers. Furthermore epidemiologic data on occupational interstitial lung diseases, in general, is limited by no standardized diagnostic criteria, varied physician awareness and training, limitations inherent to the various data sources, and the long latency period. Therefore, to optimize the management of the patient with occupational pathology, the collaboration and skills of the multidisciplinary at the service of the patient, play a fundamental role. In particular, radiologists should give substance to a clinical suspicion on an anamnestic basis and at the same time recognizing patterns of illness that can lead to the emergence of stories of misunderstood exposures. This article aims to provide an overview of the main occupational lung diseases with attention to diagnostic possibilities of the different imaging techniques. The issue of the radiological error is investigated providing tools to minimize it in the daily practice.

**Introduction**

There are relatively few papers available in the literature on the underreporting of occupational lung disease, even though problem that has been known for a long time. In 2010 two Pubmed search strings determinants (one more specific, the other more sensitive) were proposed to retrieve information on the possible association between occupational risk factors and some pathologies.[1] Using *underreporting* AND *respiratory disease*, *underreporting* AND *lung disease*, *underreporting* AND *pneumoconiosis* in the last 10 years only 23 papers were found with the specific string (21 highly pertinent). The sensitive string came up with almost the same articles retrieved by the specific one. These articles mainly concerned the underreporting of occupational lung cancers and mesothelioma. Actually, the ratio of lung cancer cases to mesothelioma cases is much lower than

epidemiological studies indicate must be occurring.[2]

The existing differences in the various national reporting systems do not even allow comparison between different countries. In Europe, there is not a common regulation even for the recognition of occupational cancers.[3] Furthermore epidemiologic data on occupational interstitial lung diseases, in general, is limited by no standardized diagnostic criteria, varied physician awareness and training, limitations inherent to the various data sources and the long latency period. This leads to underreport occupational lung diseases.[4,5]

Almost all countries have regulations that require physicians reporting occupational diseases; however underreporting is substantial and it is difficult to get stable improvements. The New York Department of Health's Bureau of Occupational Health with a communications campaign raised the physician awareness about the occupational lung diseases, but the campaign was not so successful in promoting sustained reporting.[6] If it seems difficult to increase general practitioner reporting, more promising results are obtained by raising awareness among medical specialists. In 2002 a voluntary surveillance system of occupational respiratory diseases was implemented in Catalonia (Spain) to compare them with those reported by the compulsory official system.[7] It was demonstrated that the compulsory official system seriously underreported occupational lung diseases. These authors concluded that a surveillance program based on voluntary reporting by physicians may provide better understanding of the incidence and characteristics of these diseases.

The problem of health damages coming from compounds used in the workplace has been known from long time, and this problem has been growing with human activities and progress.

Technological advances, new sources of exposure and the adoption of safety measures for known hazardous substances are leading to a change in geographical distribution and in the patterns of presentation of occupational pathologies. As a consequence there is the need to keep up by adopting new countermeasures from all the professional figures who collaborate in the safety and health of the worker.

To optimize the management of the patient with occupational pathology, the collaboration and skills of the multidisciplinary team which should be at the service of the patient play a fundamental role.

In particular radiologists play a fundamental role in giving substance to a clinical suspicion on an anamnestic basis and at the same time recognizing patterns of illness that can lead to the emergence of stories of misunderstood exposures.

This review aims to provide radiologists with tools to minimize possible errors that lead to underreporting of occupational lung diseases.

**Occupational Lung diseases**

Occupational lung diseases consist of a wide spectrum of disorders resulting from the inhalation of particles (chemical, biological) affecting pulmonary parenchyma, airways or pleura.[4] Finding a correlation between exposure and disease is challenging because there are no specific patterns of clinical or radiological presentation. Thus a single agent can have a variety of manifestations such as asbestosis and different sorts of exposure that can lead to the same pulmonary disease, for example, hypersensitivity pneumonitis (HP). No reliable figures exist for the total incidence or prevalence of occupational lung diseases. Work-related asthma is the most common chronic occupational lung disease in developed countries, where occupational asthma accounts for about 15% of all adult-onset asthma, while occupational agents are estimated to be the cause of 15% of chronic obstructive pulmonary disease (COPD).[4] The incidence of silicosis and asbestosis is decreasing in developed countries and the clinical cases that are observed are less severe. Below, we discuss a general description of main diseases and their peculiarity, in order to understand the burden of diseases and the most frequent problems the radiologist has to face in his/her practice.

***Non-malignant Asbestos-related disease***

Asbestos refers to a group of minerals (hydrated magnesium silicate minerals) widely used by industry in past times but less so today. It has been used in in roofing, insulation, brake pads, and gaskets, and in various workplaces and construction sites. Its role as a carcinogenetic factor has been recognized from the scientific community leading to a ban of asbestos in 55 countries around the world.[8] Instead of stopping the production the ban has generated a shift in geography distribution to less developed countries and 125 million workers are still directly exposed worldwide.[9] Countries who banned asbestos are facing the problem of residual effects of previous occupational exposure and the effects of the remaining asbestos product (asbestos "in situ").. Countries that did not ban asbestos are going to experiment with an unmitigated disaster, with the only difference being the availability of more advanced preventive measures that should, in theory, contain the phenomenon to a certain extent.[10]

Because of this protracted consumption and the long latency of clinical manifestations, the peak of incidence of asbestos related diseases will be reached between 2020 and 2030.[11] Even in more developed countries asbestos-related problems occur and new challenges are coming to clinicians and radiologists in recognizing the disease despite lower levels of exposure. Both malignant and nonmalignant asbestos-related diseases can potentially lead to death even if the mortality rate, because of the problem of underreporting, remains unknown.

Non-malignant asbestos-related diseases refers to asbestosis, pleural thickening or asbestos-related pleural fibrosis (plaques or diffuse fibrosis), "benign" pleural effusion and airflow obstruction.[12] Malignant diseases related to asbestos include mainly lung cancer, with the highest mortality, and mesothelioma. Other correlations have been found for gastrointestinal, ovarian and larynxeal cancers.

From a radiological point of view, pleural plaques (PP) are the most common form of the pleuro-pulmonary abnormality consistent with asbestos exposure, and are considered to be a marker of exposure, indicating an increased risk of pulmonary fibrosis or asbestos-related malignancies versus

the general population (Figs. 1-3).[13] In fact PPs may be a risk factor for mortality from lung cancer in asbestos-exposed workers, particularly in either smokers or former/ex-smokers.[14] Moreover the presence of PPs may help in considering asbestosis as a cause of interstitial lung disease predominating in the sub-pleural area of the lower lobes.[15] Furthermore a recent Japanese study found that in lung cancer patients, the plaque extent had a significant positive relationship with the asbestos body concentration in lung tissue that represents a biomarker of past exposure.[16,17] Pulmonary involvement caused by the inhalation of asbestos fibres is called asbestosis. Asbestosis is less common than pleural plaques in asbestos-exposed workers, but there are no good studies on its prevalence. The inflammatory process induced by asbestos include alveolitis, inflammation in the surrounding interstitium, and inflammation followed by fibrotic change in the respiratory bronchioles that extends into adjacent alveolar tissue.[18] For this reason, the early HRCT findings of asbestosis are the dot-like opacities (peribronchiolar ground-glass nodules) and the more specific subpleural curvilinear lines caused by the confluence of dot-like opacities (Fig. 4). Advanced HRCT findings of asbestosis are not specific (septal lines, reticular opacity and finally honey-combing) which means a possible overlapping with other causes of pulmonary fibrosis (Fig. 5).[19,20] In a recent study by Arakawa et al[15] the authors claimed that even if various patterns of pulmonary fibrosis could occur in asbestos-exposed workers, sub-pleural curvilinear lines were the only clue for the diagnosis of asbestosis. Mosaic perfusion due to airway obstruction, emphysema, ground-glass opacity due to alveolitis, traction bronchiectasis, parenchymal band, coarseness, consolidation and round atelectasis are other possible but not specific HRCT features in asbestosis (Fig. 6).

***Hypersensitivity pneumonitis***

Occupational ypersensitivity pneumonitis (OHP) also known as extrinsic allergic alveolitis (EAA), is a complex syndrome resulting from an exaggerated reaction to repeated exposure to a variety of antigenic particles found in the environment.[21] It is a such a complex disease that a precise

definition has not been accorded.[22,23] Agents described as potentially causative of HP can be found in a variety of occupations and can be classified in six categories: bacteria, fungi, animal and plant (glyco)proteins, low molecular weight chemicals, and metals.[24]

As working practices have changed, some causes of OHP have markedly declined (e.g. farmer's lung) while new exposures are emerging such as metal working fluids, implicated as a causative agent of HP among machine operators.[10,25,26] A recent paper by the European Academy of Allergy and Clinical Immunology (EAACI) describes six significant predictors for diagnosis: (i) exposure to a known offending antigen, (ii) positive specific IgG (precipitating) antibodies to the offending antigen, (iii) recurrent episodes of symptoms, (iv) inspiratory crackles, (v) symptoms occurring 4–8 h after exposure, and (vi) weight loss. The association of these six criteria provides a probability of 98% of having HP.[24] What we can understand from such criteria is that to reach diagnosis of HP, a multidisciplinary approach involving clinicians, radiologists, pathologists, and occupational physicians/hygienists is required. However the role of imaging in these clinical conditions is increasing as demonstrated by the proposed diagnostic criteria for OHP suggested by some authors that included findings compatible with HP on chest radiograph or HRCT in the major criteria for these conditions; whereas precipitating antibodies to HP antigens were included in the minor criteria because of the difficulties in obtaining this data due to the variety of antigenic particles found in the environment.[27] However the possibility of OHP should be considered in all cases of interstitial or diffuse lung disease of unknown etiology and in patients with relapsing respiratory and flu-like symptoms that are work related.[24] Removal from exposure to the causal workplace agent is the recommended treatment of OHP, although the possibility of an adverse outcome has been described even after avoidance of exposure.[24] From a radiological point of view, OHP could manifest with a variable spectrum of features, mainly depending on the time passed from the exposure. HRCT features of OHP are usually schematize (sketch) in acute (ground-glass opacities, micronodules, mosaic perfusion, emphysema, mediastinal lymphadenopathies), subacute (generalized increase in attenuation of the lung, nodular pattern, reticular pattern, patchy air space

opacification, ground-glass attenuation) or chronic features (emphysema, micronodules, septal lines, reticular pattern, fibrotic ground-glass, honey-combing); however in the majority of affected patients these three forms could be overlapping and in particular acute and subacute CT features.[27-30] However, since the OHP could manifest with a variable spectrum of radiologic findings that may mimic a wide range of lung diseases, an accurate work investigation, together with pharmacological and smoked-related investigation, should always be obtained in every patient who undergo HRCT of the lung (Figs. 7-10).

*Silicosis*

Silicosis is caused by the inhalation of crystalline silicon dioxide or silica and is one of the most important occupational diseases worldwide.[31] Workers at risk are in the field of masonry and plastering, heavy construction, painting and paper hanging, iron and steel foundaries, metal services and many others.[32]

Newly recognized causes of accelerated silicosis and silicoproteinosis are sandblasting denim clothing occurring mainly in developing countries where few exposure controls exist,[33, 34] and artificial quartz conglomerates containing high levels of crystalline silica particles (70-90%) used in the construction of kitchen and bathroom surfaces.[35] Several epidemiologic studies have reported statistically significant numbers of excess deaths or cases of immunologic disorders and autoimmune diseases in silica-exposed workers. These diseases and disorders include scleroderma[36], rheumatoid arthritis[37], systemic lupus erythematosus[38], and vasculitis.[39] Furthermore recent epidemiologic studies have reported statistically significant associations of occupational exposure to crystalline silica with renal diseases and subclinical renal changes.[40] There is a strong association between silicosis and TB but some studies are showing that TB can be developed with exposure to silica without silicosis.[41,42] Occupational exposure to respirable crystalline silica is also associated with bronchitis, COPD, and emphysema[32] even if some epidemiologic studies suggest

that these health effects may be less frequent or absent in nonsmokers. Diagnosis of silicosis generally relies on a history of substantial exposure to silica dusts and compatible radiological features, together with exclusion of other differential diagnoses (TBC, sarcoidosis, IPF, carcinomatosis, other ILD).[31] However, one should consider that both the pathological and radiological characteristics of silicosis have changed because even though they are rarer in developed countries, they can now be diagnosed at an early stage. In fact, diagnosis is more straightforward during the phase of bronchiolitis with small airway lesions that are caused by mineral dust exposure, similar to the earliest phases of asbestosis. First-order respiratory bronchioles are the most severely affected and the injury is greatly accentuated by tobacco smoking (Figs. 11 and 12).[43]

***Malignant Asbestos- related diseases***

***Lung Cancer***

Some studies estimates that 2% to 8% of total cancer is attributable to occupational exposures.[44] Lung cancer is the main occupational related disease that can lead to death representing the most lethal consequence of exposure to asbestos[45], silica[46] and other compounds such as beryllium.[47] Underreporting and undercompensation of lung cancer are wide problems for the various funding systems of various nations.[44,48-50] From a radiological point of view, radiologists who are involved in the CT reporting of a lung cancer should always check to see if there are pleural plaques that would suggest correlation to an occupational exposure (Fig. 13). A systematic review of occupational asbestos exposure and lung cancer revealed that histology and location are not helpful in differentiating asbestos-related lung cancer, whereas pleural plaques, asbestos bodies, or asbestos fibers are useful as markers of asbestos exposure. Furthermore, since the interaction between asbestos and smoking in regard to lung cancer risk is between additive and multiplicative,

radiologists should also be informed about pack-years of smoking of the subjects subjected to the CT investigation.[5, 45, 51]

***Mesothelioma***

Malignant pleural mesothelioma (MPM) is the most common primary neoplasm of the pleura. MPM has a poor prognosis and a strong association with asbestos exposure which has been understood since 1960.[52] The role of asbestos is important not only as primer but recent studies also demonstrate that MPM may become clinically apparent at a younger age in heavily exposed subjects, suggesting a role in the progression of disease.[53] Moreover both the time and the dose of exposure seems to play a central role[54] on the probability of developing MPM. Unfortunately, the prognosis of MPM is poor with a median survival after diagnosis between 4 and 18 months.[55]

**Imaging Technique**

*Chest X-ray*

Historically the chest X-ray represents the first imaging step in evaluating the presence and the extent of occupational disease. With its low cost, widespread availability and low radiation dose, currently the chest X-ray is the main modality for screening pneumoconiosis[33]. However, to obtain a more in depth evaluation of diseases, many studies demonstrate the higher accuracy of HRCT.[56-58] From 1980 a standardization for performing and reading chest X-ray of occupational disease has been promoted by the International Labour office (ILO) supported by the National Institute for Occupational Safety and Health (NIOSH) and the American College of Radiology,[59] with the last revision of 2011.[60] However since we are seeing a progressive reduction in exposure levels to substances known to cause pneumoconiosis, the chest x-ray even if inexpensive, widespread and

associated with low doses cannot provide for effective detection of lung involvement developed with today's exposure levels, resulting in a high false negative number for pleural plaques and false positive number for parenchymal involvement (Fig. 14).[33]

***Tomosynthesis***

Tomosynthesis is a method for performing high-resolution limited-angle tomography at low radiation dose levels. Dose is equal to 2 or 3 chest X-rays and 2% of average CT dose.[61] Implementing tomosyntheis in a radiological department could lead to a reduction in CT examinations with resulting reductions of costs and dose.[61] In a recent publication about the comparison of chest digital tomosynthesis (DTS) and chest radiography for detection of asbestos-related pleuro-pulmonary disease, using a low-dose MDCT in the prone position serving as the reference standard, the authors reported that inter-observer agreement regarding DTS findings was moderate to very good ($k = 0.544$-$0.846$) and superior to the radiographic findings ($k = 0.236$-$1.000$). Overall, the diagnostic accuracy of DTS for lesion detection was significantly better than with radiography (all $p < 0.05$). Furthermore DTS was more sensitive than radiography for the detection of asbestosis (82% versus 27%, $p = 0.031$).[62] However even if tomosynthesis could be a great instrument, it shows some limitations compared to HRCT, particularly in the evaluation of early stage of asbestosis or little ground glass opacities.[63]

***High Resolution Computed Tomography (HRCT)***

HRCT technique has changed a lot through years. From the so called “gapped HRCT”, with the implementation of multidetector CT, it became possible to acquire volumetric CT, reducing

acquisition time and reconstruction slice thickness.[57] HRCT is the most accurate instrument in the evaluation of occupational diffuse lung diseases because it allows the visualization of signs of early asbestosis such as very thin pleural plaques that are undetectable by chest X-ray examination. In an interesting study by Dr. Terra-Filho M and colleagues[58], chest radiography (CXR) results were judged unequivocally inferior to thin-section computed tomography in the detection of asbestos related interstitial and pleural abnormalities. The authors in evaluating clinical, CXR, and thin-section CT data obtained in 1418 miners and millers, who were exposed to progressively lower airborne concentrations of asbestos, demonstrated that CXR suggested more frequently interstitial abnormalities and less frequently pleural plaques than observed on thin-section CT ($p<0.050$). Furthermore the likelihood of diagnosing asbestosis in groups with reduced exposure is lower with thin-section CT than CXR, suggesting false positive results at CXR examination.[58] Currently, the HRCT protocol should comply with the following standards: a) Since the most common involvement of asbestosis is in the posterior zones of the lungs, the patient should be studied in the prone position to avoid dependent opacities consisting of ill-defined areas of increased subpleural lung attenuation arising in areas of passive microatelectasis and also attributed to fluid accumulation caused by gravity. These ill-defined densities which could simulate or hide fibrosis are almost eliminated in the prone position. Also minimized is the confusion created by functional pleural thickening seen in the supine position but not as much in the prone. (Figs. 15 and 16)[64] ; b) The study should be performed using spiral acquisition at full inspiration, in order to cover the entire lung volume, to avoid overlooking small pulmonary nodules; c) The slice thickness should not exceed 1.5mm (best if $\leq$ 1.25mm) and reconstruction interval should range from 1/3 to 1/2 of effective slice thickness in order to characterize tiny parenchymal and pleural alterations (Fig. 17). Other technical suggestions include field of view (FOV) as small as possible and limited to the lung parenchyma to increase the spatial resolution, and the use of a small focal spot (the mA should be adjusted to the particular scanner used), and finally a kVp ranging from 120 to 140 should be chosen depending on the body size of the patient. Expiration scans should be performed when the

radiologist suspects an obstructive condition or lung mosaic perfusion attenuation is visible in the inspiration scans. If the radiologist is concerned about nodular area, a small FOV axial scan of a few slices should be obtained to improve the spatial resolution useful in the characterization of nodule margins (Fig. 18).[65] Thus, the performance of HRCT is a dynamic CT examination, and its method of acquisition should be modified according to the clinical situation. This a reason why radiologists should perform this examination side by side with the radiographers. The development of a standardized CT scoring system is ongoing (International Classification of HRCT for Occupational and Environmental Respiratory Diseases – ICOERD[66]), and it has shown good inter-reader agreement and also seems to show agreement with chest X ray findings[67]. However, the feasibility of HRCT on populations with low level of exposure has not as yet been explored. Although HRCT has also been proposed as a screening method, the high costs and dose are important obstacles.

For this purpose low dose CT (LDCT), which is defined as a CT scan performed with a dose lower than conventional CT, has gained popularity for screening of smokers with high risks of lung cancer after the publication of the results of the National Lung Screening Trial (NLST) in US[68,69]. Several papers suggest that exposure to occupational substances could lead to a similar risk of developing lung cancer as 30 p/y smokers, making results of the NLST applicable also for occupational diseases.[70] However LDCT is not an appropriate tool to detect and characterize minimal alterations of lung parenchyma such as early asbestosis and therefore should not be recommended for evaluating patients with exposure to asbestos.

**Role of Radiologist**

In the management of occupational lung disease, radiologists can commit a variety of errors, both in the direction of over- and underreporting. Errors could be avoided with awareness of the occupational history, familiarity with radiological signs of occupational diseases, knowledge of how to optimize CT technique, and finally effective communication as to how to manage diseases.[71]

However if radiologists want to be confident with the evaluation of occupational lung diseases they need to acquire particular knowledge in this field, through both experience and study. For the radiologist, an advantage of working with occupational diseases is that the patient is never managed by only one medical professional but with other specialists through a multidisciplinary approach.

***The radiologist should be aware of the occupational history of the patient***

A radiologist who is not aware of a patient's occupational history, is more likely to make a mistake, especially in the direction of underreporting. The medical history, collected by an occupational physician and possibly also by the radiologist, should be as complete as possible and should include the character of the exposure (intensity, time of duration, and also the lapse of time passed in case of cessation) and other possible factors capable of causing alterations which are potentially confoundable with those of work-related diseases such as smoking, asthma, interstitial diseases, rheumatological diseases and pharmacological anamnesis.[72] Learning and exchanging views with an occupational physician or other professional individual, in the context of increasingly multidisciplinary medicine, should be the normal and not an exception. Other investigations performed before the radiologic examination can provide key information to aid in the interpretation of the examination itself. In particular, pulmonary function tests give the radiologist the ability to examine the images in the light of an objective assessment of the patient's respiratory difficulties. By combining the two data sources, it is possible to be more precise in defining lung disease pathophysiology, severity, management, response to treatment, prognosis, and impairment.

***The radiologist must know technical possibilities***

It is essential that the radiologist choose the most appropriate technique to use in the investigation of occupational disease.

In Italy, the responsibility of the examination, according to the legislative decree 187/00, following the principle of justification, falls both on the prescriber and on the radiologist. The radiologist's specific task is to comply with the optimization principle, exposing the patient to the lowest doses able to give the information sought. When the choice of technique to be used has been agreed on, the radiologist should adopt all the strategies necessary for the best outcome of the examination at the least possible dose. With regard to chest X-ray, the correct positioning of the patient, full inspiration and the voltage and amperage parameters are fundamental.

On HRTC, on the other hand, there are many more variables involved and considering the different dose to patient risks are greater. Some CT technical parameters are essential in performing a high resolution CT examination of the thorax: the use of thin sections (0.5–1.5 mm), a high resolution algorithm for the reconstruction of images, the smallest field of view (FOV) that encompasses the lungs, and finally it is essential to obtain the HRCT images during a suspended full inspiration. However, radiologists should be also able to complete the HRCT examination with an expiratory or post- expiratory scan (for example to confirm the presence of an obstructive airway disease) or to decide when the HRCT examination should be performed in the prone position of the patient.[5]



***The radiologist must know occupational diseases patterns and characteristics***

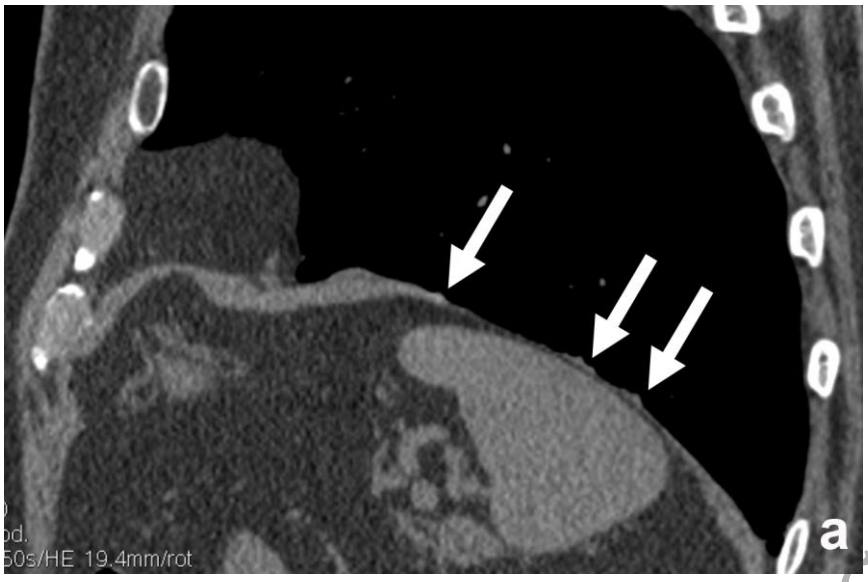
The potential to suggest or confirm a diagnostic hypothesis should be the basis of the radiologist profession. The only way to reach such goal is to know radiological signs, to recognize them and avoid potential pitfalls in the daily routine (Figs. 19 and 20). The biggest problem with occupational diseases is that usually there are not specific signs of the disease and it can be suspected only in the light of the anamnesis. At chest X-rays the classification system elaborated by International Labor Organization (ILO), with support from the National Institute for Occupational Safety and Health

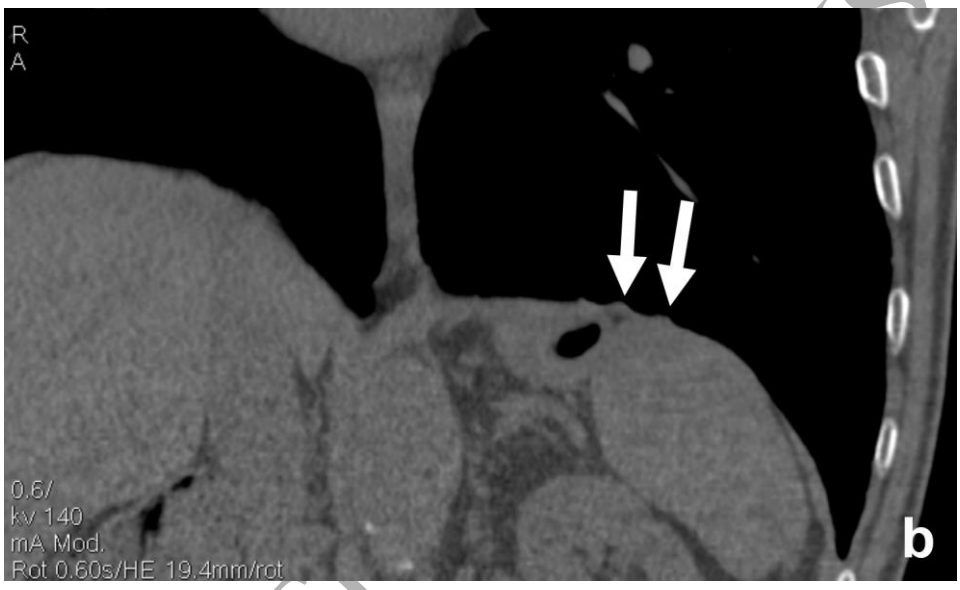
(NIOSH) gives an objective evaluation and is accepted worldwide so it represent the must know for radiologist.[60] Many classification attempts for HRCT findings of occupational lung diseases similar to the ILO system for radiographs have been developed but none is accepted.[73,74] Irrespective of the lack of standardization, occupational injury can be generally categorized into airspace, nodular, reticular, cystic, emphysematous, airway, and pleural patterns which correlate with particular exposures.[33]

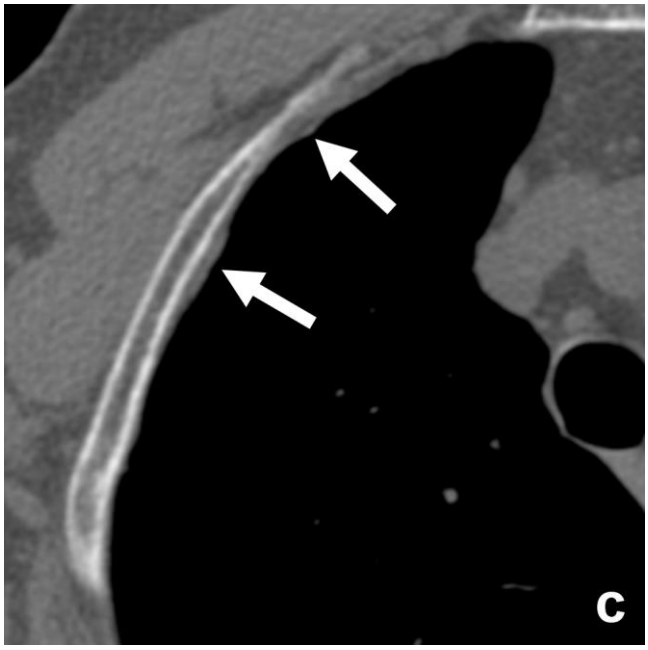
***The radiologist must be effective in communicating***

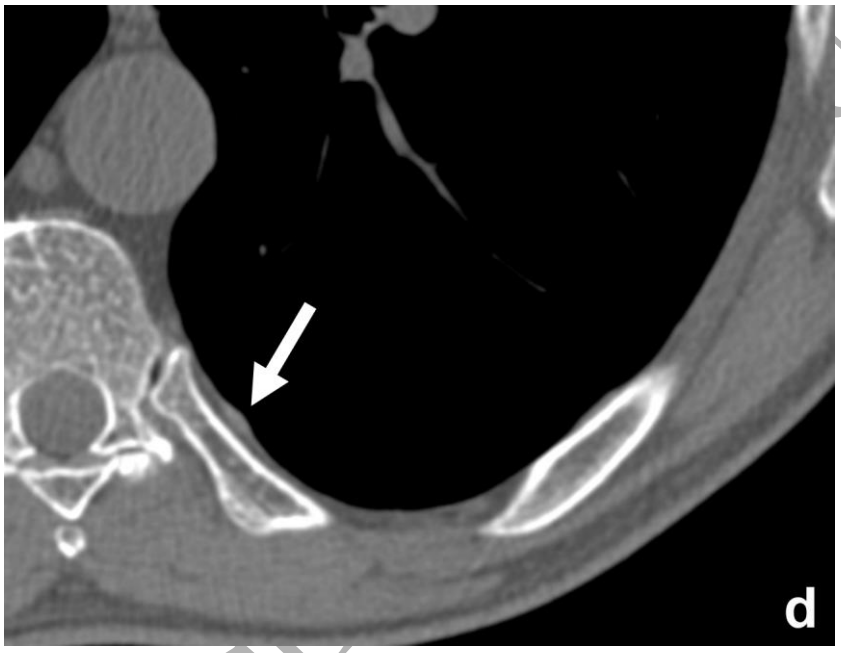
Communication is of fundamental importance in the radiologist's profession. Although competent and well informed about the patient, if the radiologist is unable to translate his conclusions into concrete changes on patient management, the job has not been done properly. Therefore, the radiologist must provide in the report an accurate description of the findings but above all direct attention to a knowledge-based diagnosis. Multidisciplinary management, starting from presuppositions of mutual listening, can only be fruitful. Moreover, in the delicate landscape of occupational diseases, we must that the radiological report may be a starting point for a notification of occupational disease and then for compensation.

## Figures legend





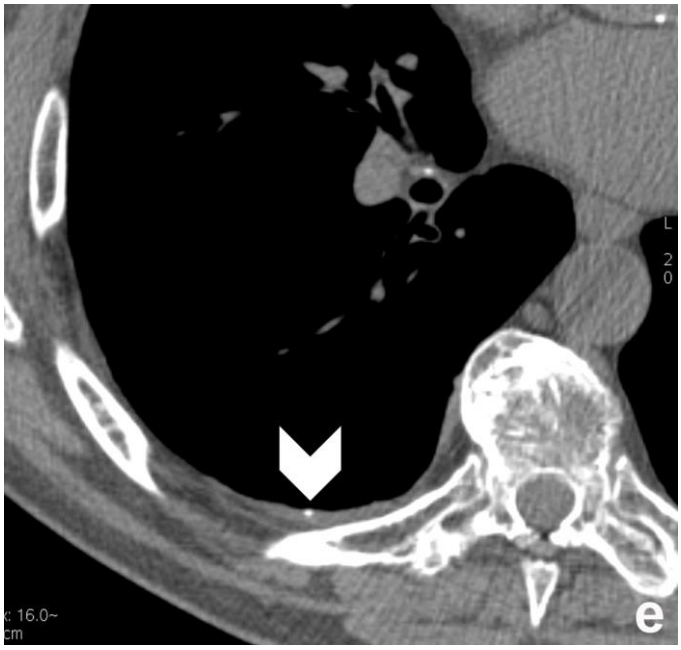
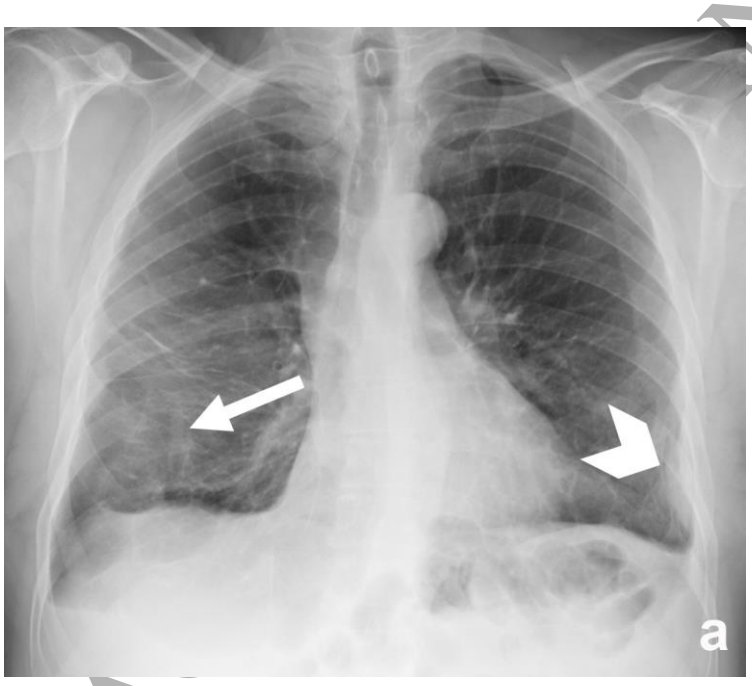
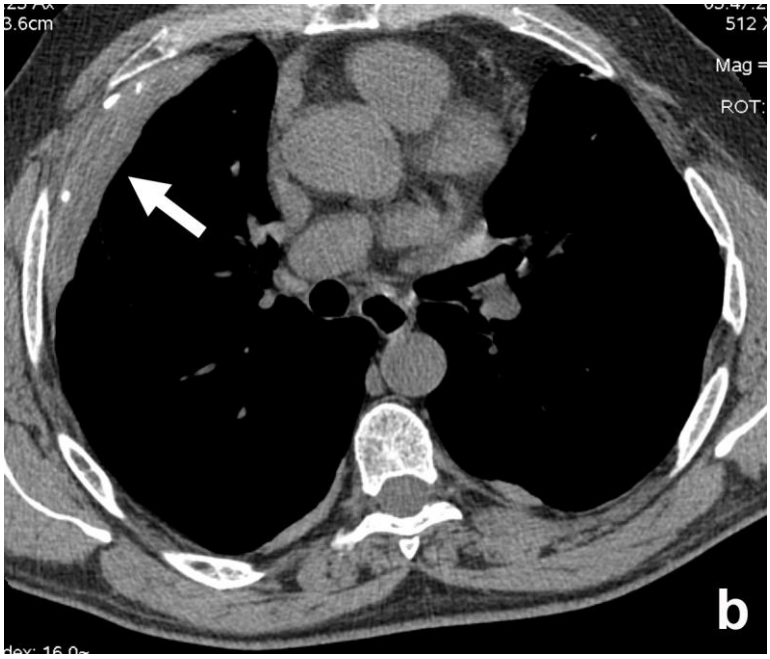



**Figure 1** (A-E) Multiple tiny non-calcified plaques distributed along the diaphragmatic (arrows in A and B) and costal pleura (arrows in C and D) and one partially calcified plaque along the costal pleura (arrowhead in E).





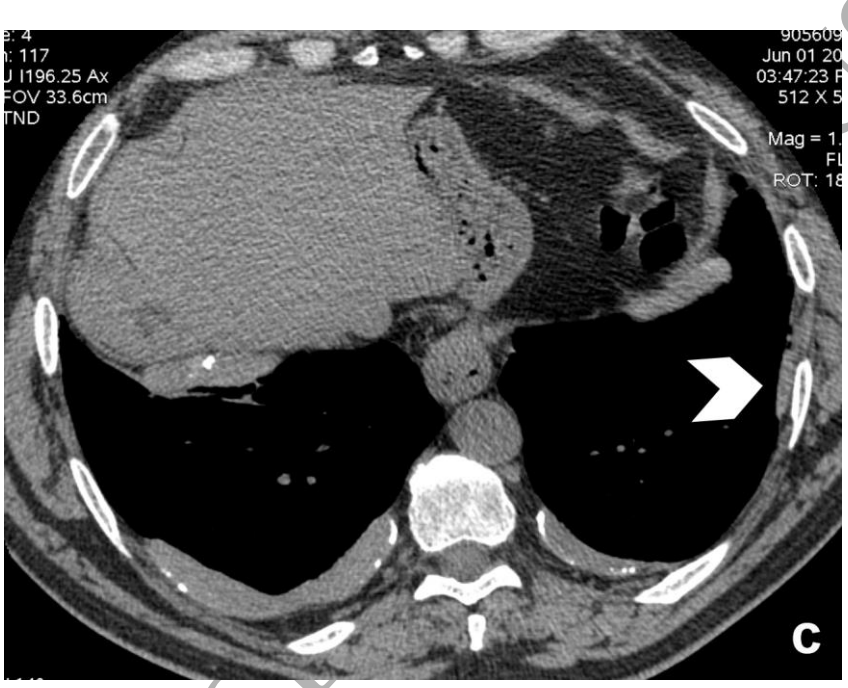
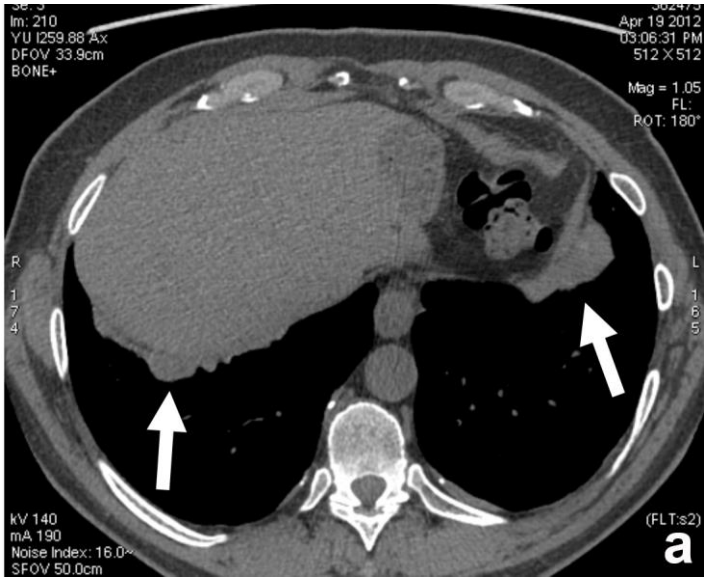




**Figure 2** (A-C) A 75 year-old man with coarse asbestos-related pleural plaques, identifiable on the standard posteroanterior radiograph: a large en face costal pleural plaque on the right (arrow in A) and a profile plaque on the left (arrowhead in A) with their corresponding images on CT.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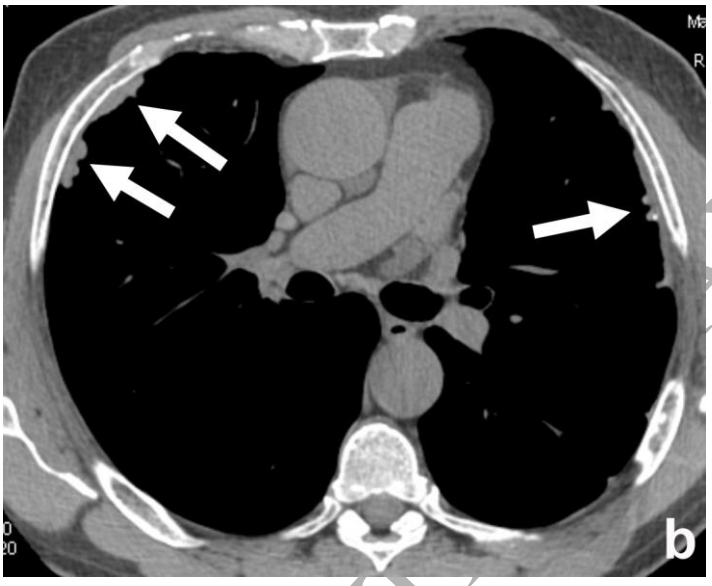
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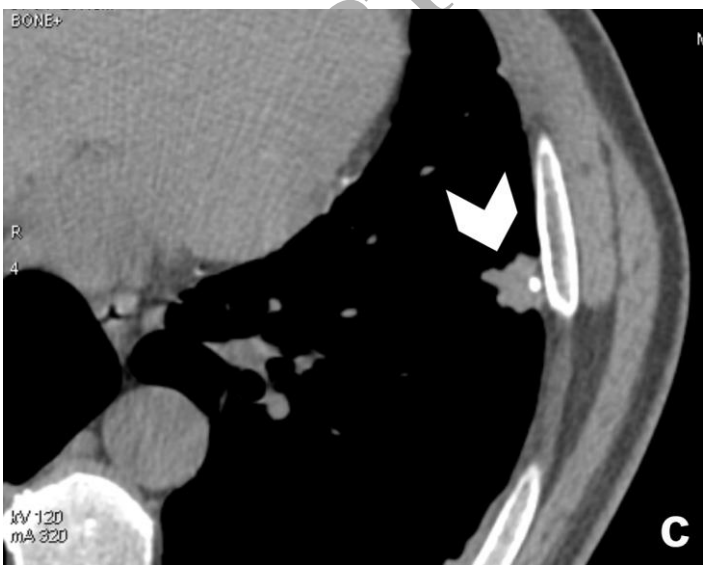
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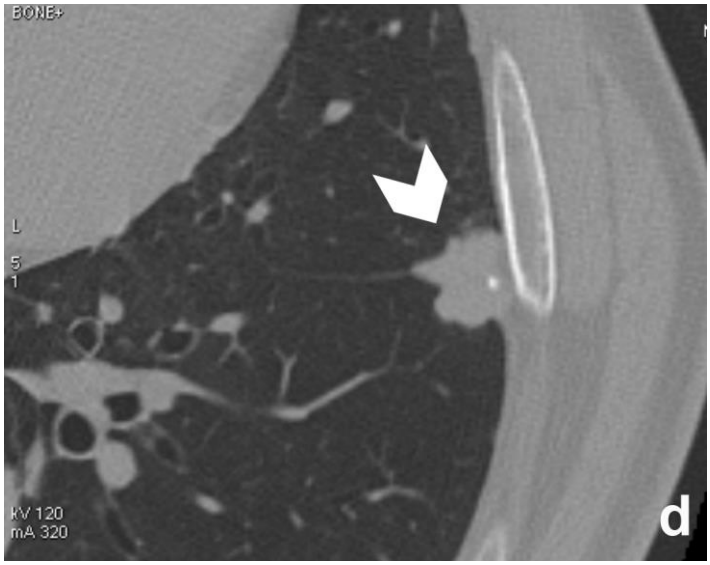
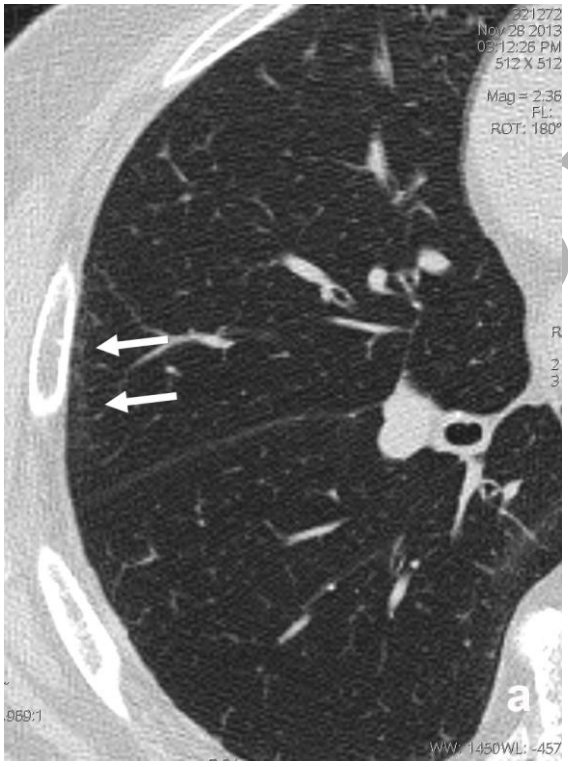



**Figure 3** (A-D) Coarse pleural plaques distributed along the diaphragmatic (arrows in A) and costal pleura (arrows in B). One plaque (arrowhead in C and D) along the left costal pleura simulates a pulmonary nodule.



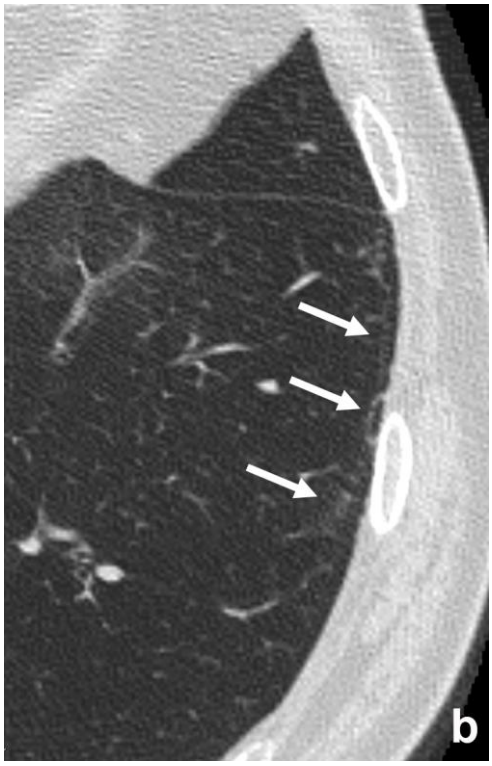
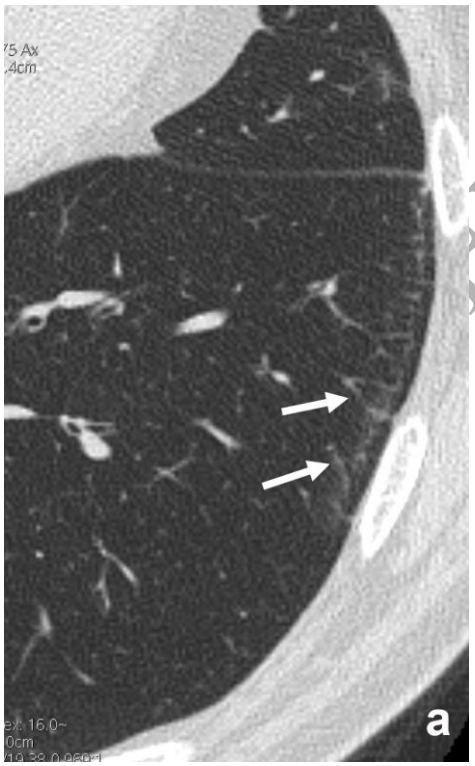



**Figure 4** (A, B) Dot-like opacities causing subpleural curvilinear lines (arrows in A and B) in early asbestosis.



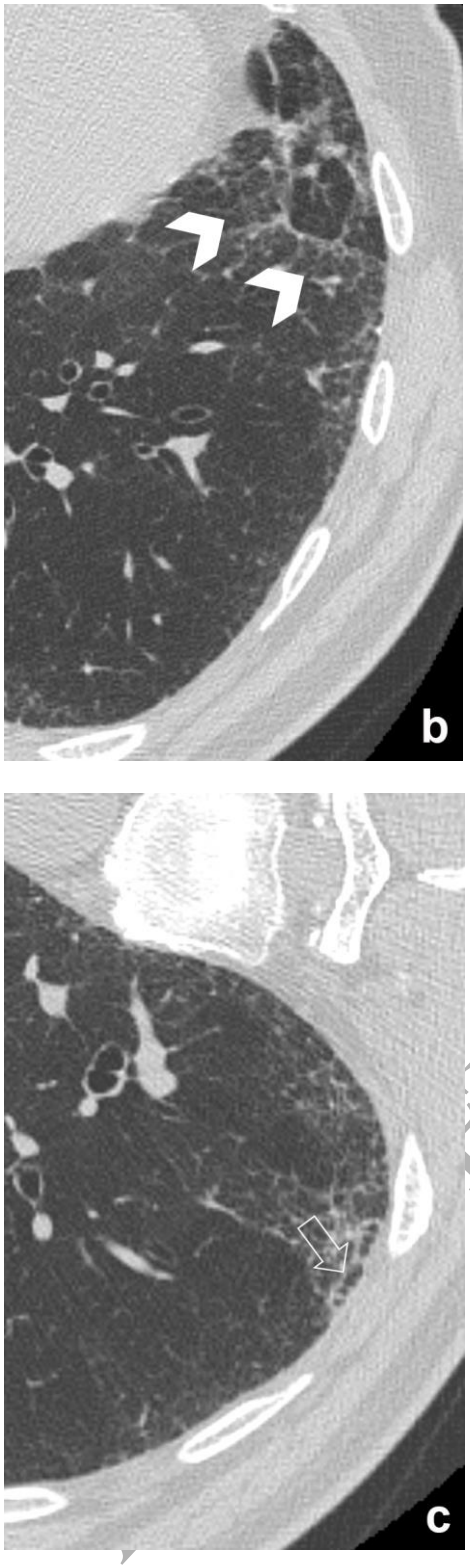
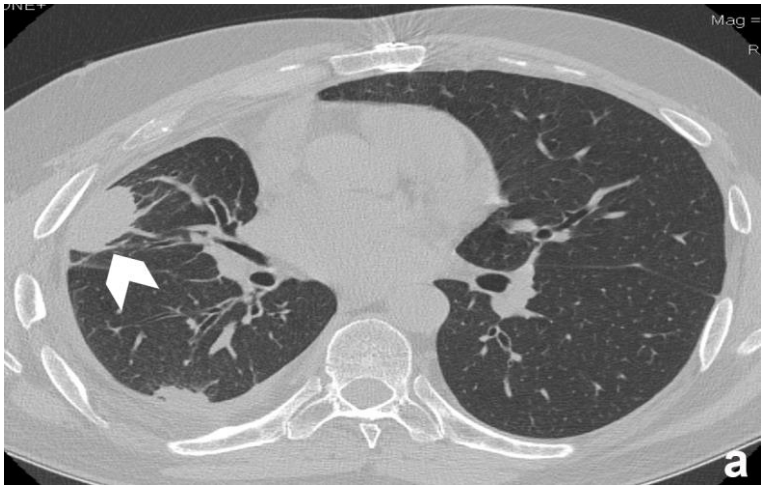
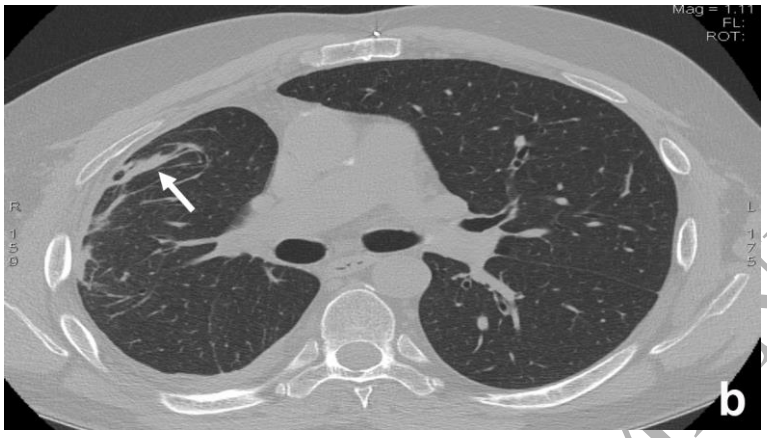
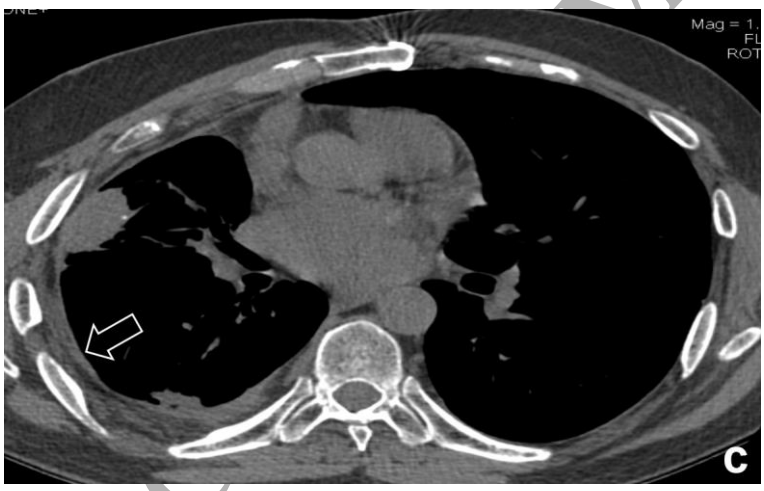
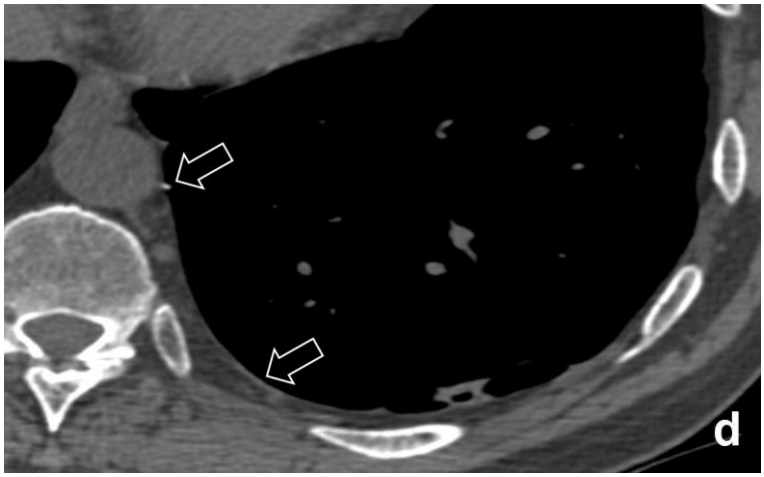


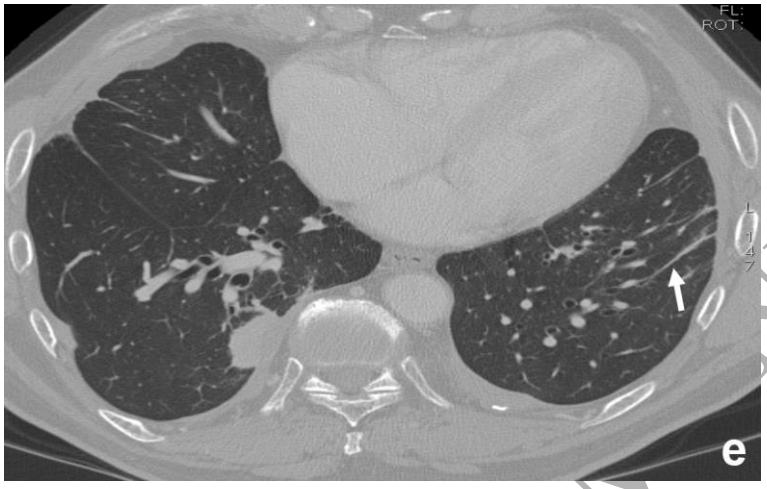

**Figure 5** (A-C) Advanced asbestosis represented by septal thickening (arrows in A), reticular opacities (arrowheads in B) and honey-combing (empty arrow in C).

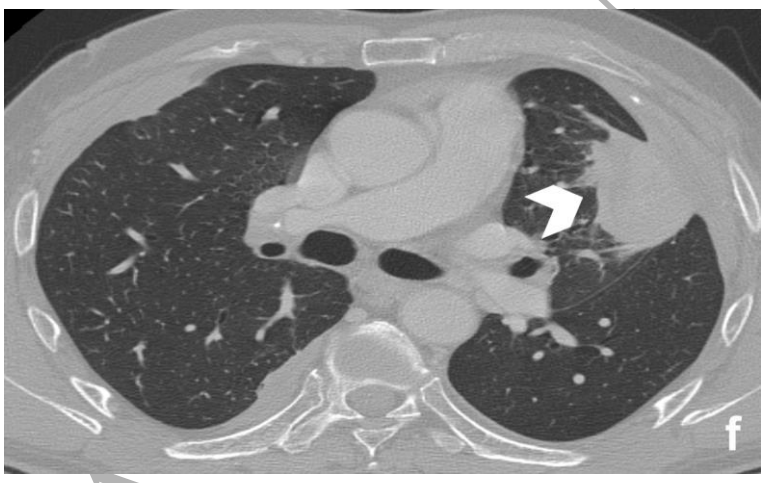




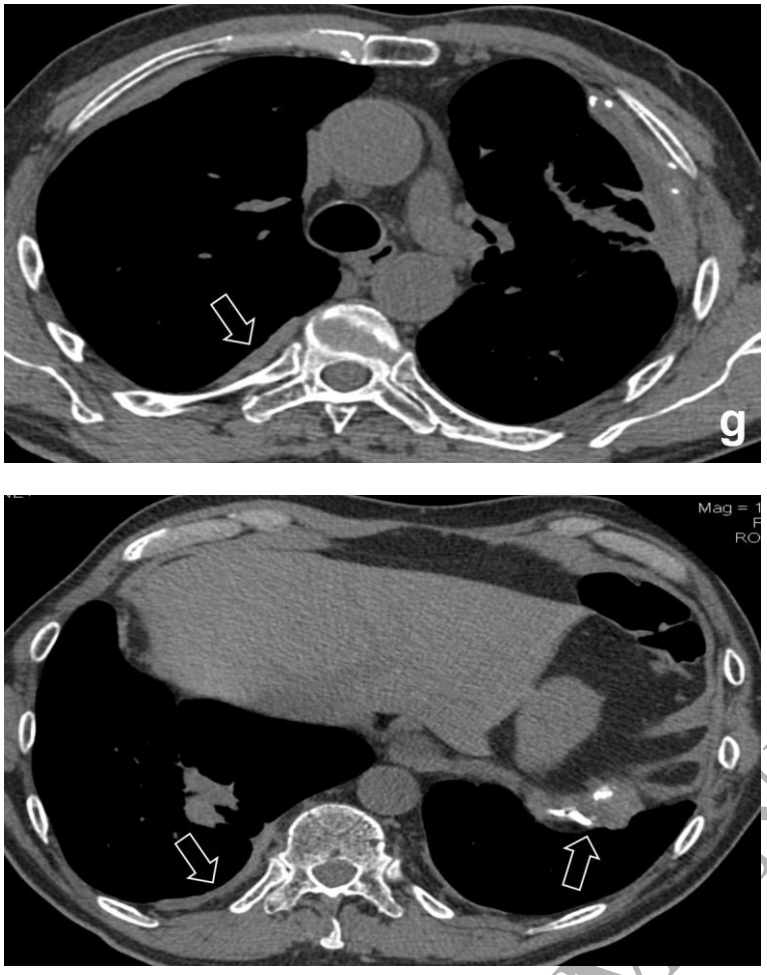
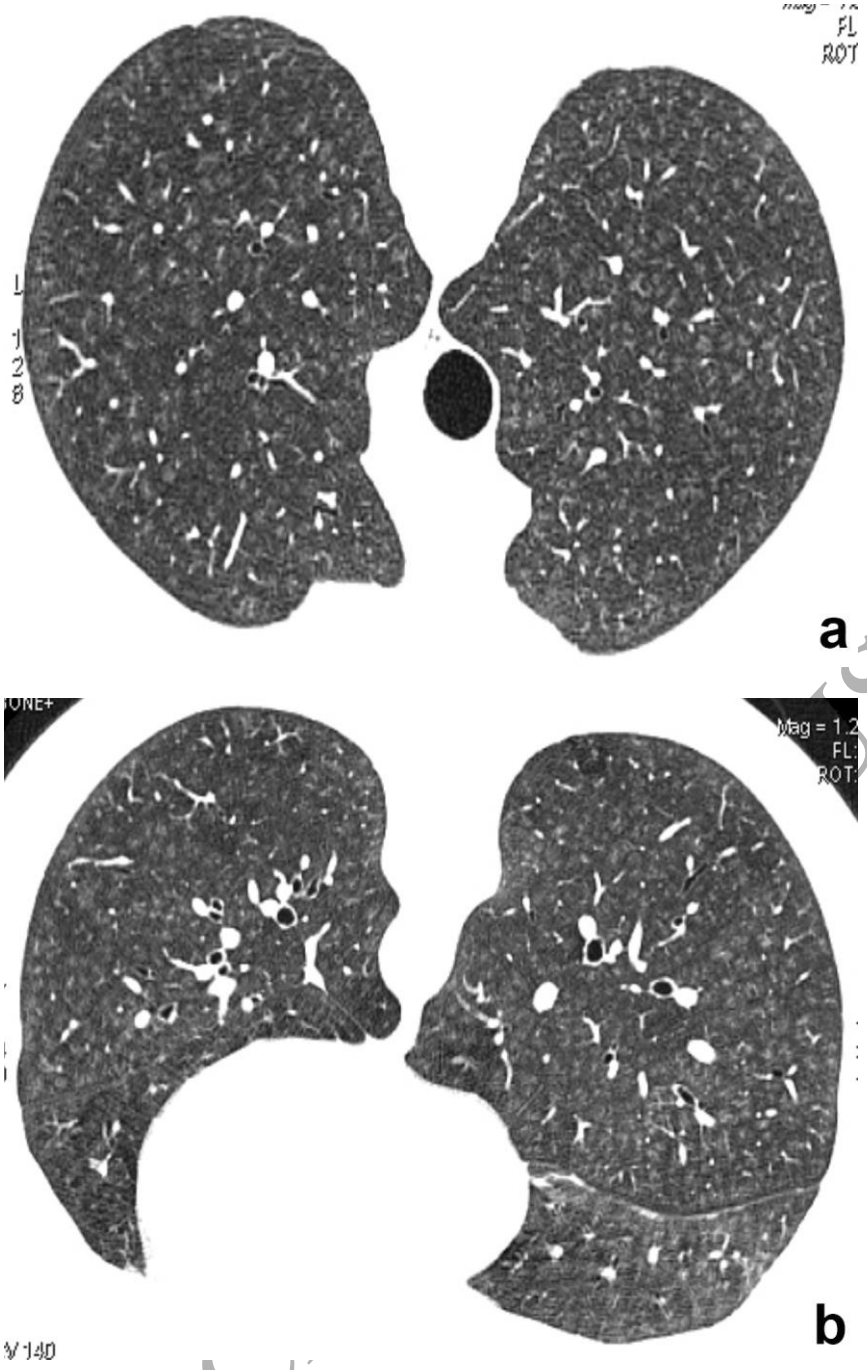



**Figure 6** (A-H) Two men of 54 and 52 year-old respectively with superimposable HRTC findings caused by different etiologies: the first case (A-D) represents the outcome of a pleuritis in a heart transplant patient whereas the second patient (E-H) was affected by asbestosis. Both cases showed fibroatelectatic bands (arrows in B and E), round atelectasis (arrowheads in A and F) and pleural thickening (empty arrows in C, D, G, H).



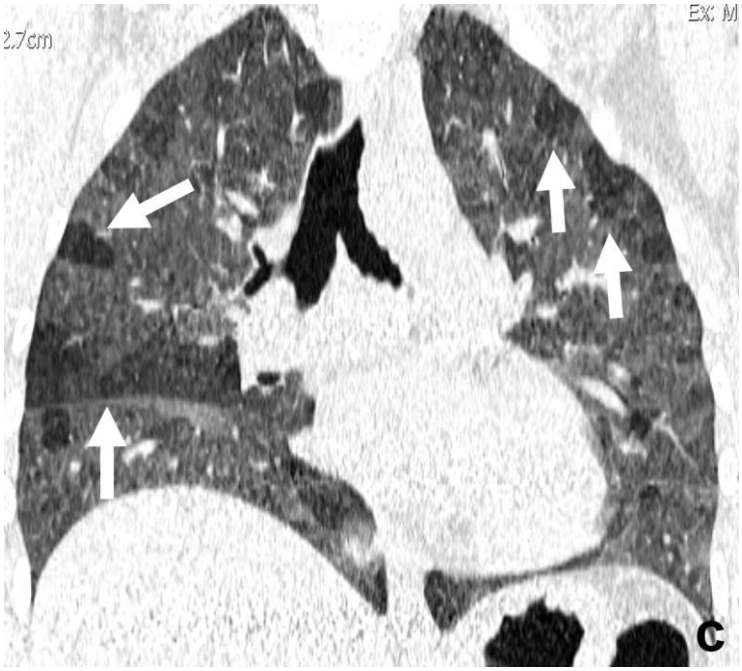
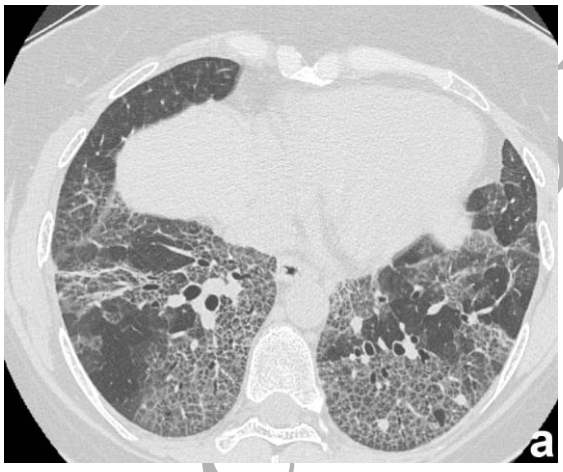
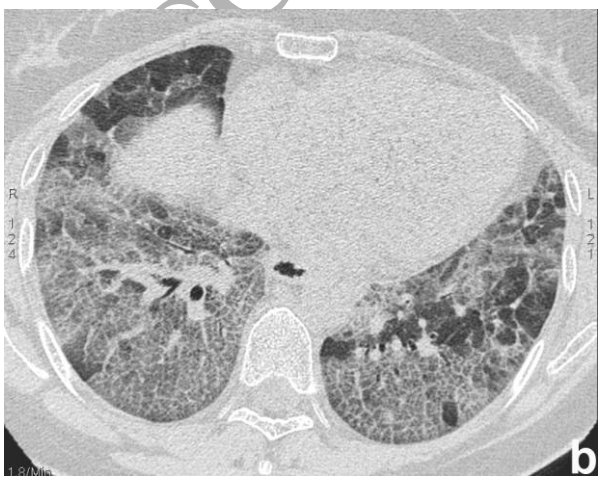
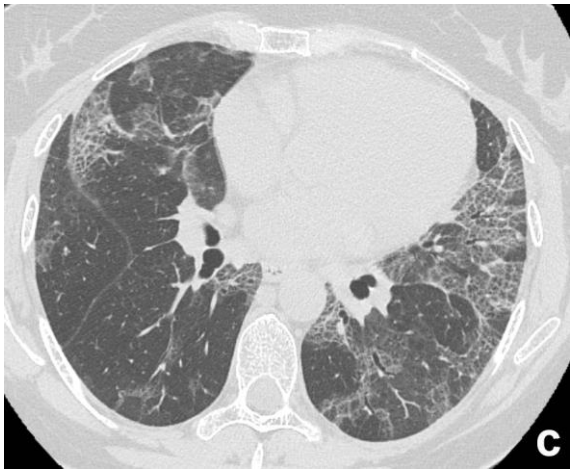
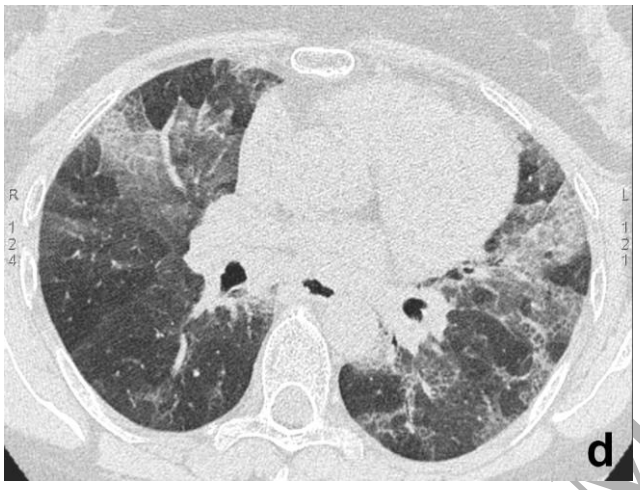


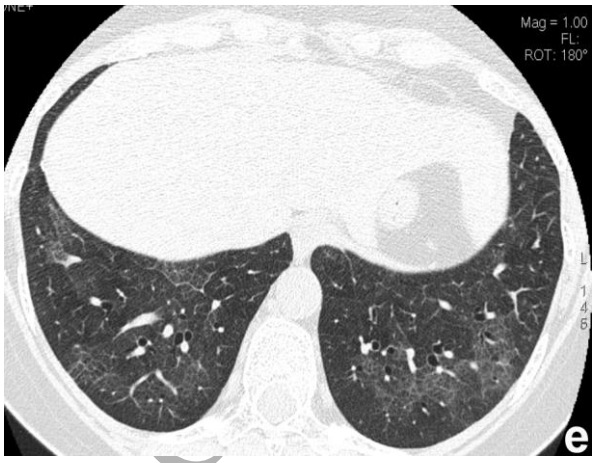

**Figure 7** (A-C) Acute hypersensitivity pneumonitis in a 56 year-old cleaning woman due to massive mold inhalation. HRCT scans of the lung (A, B) show diffuse centrilobular nodules; lobular areas of air trapping are visible on expiratory scan (arrows in C).





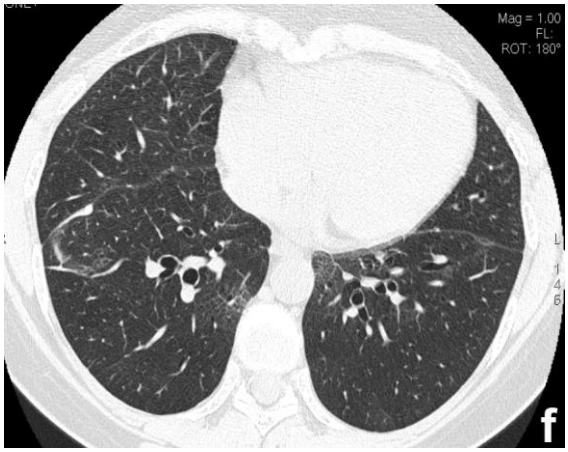
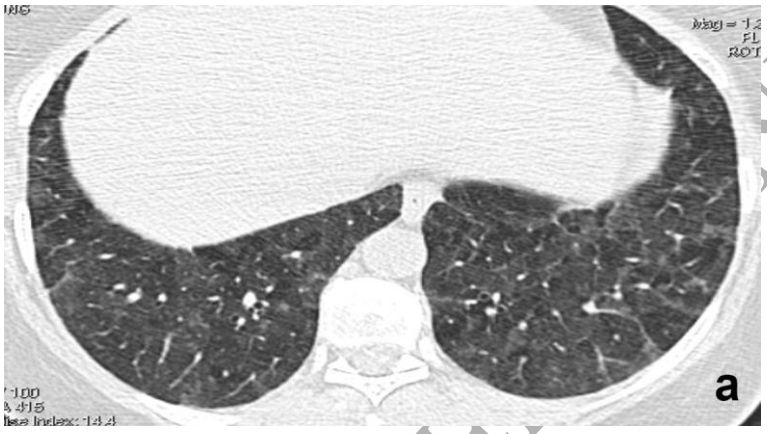
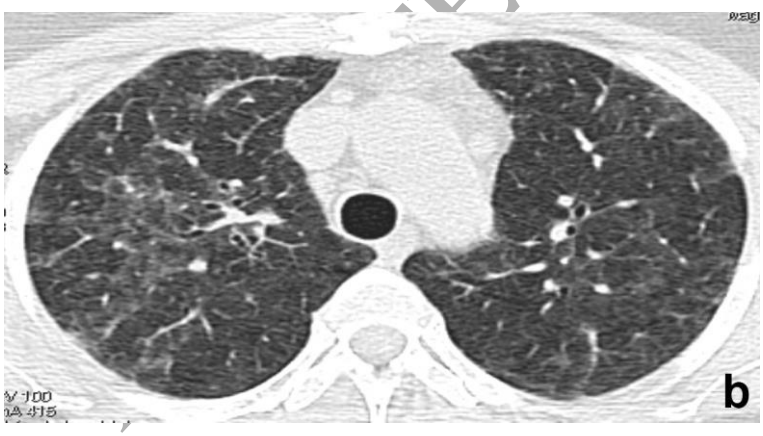



**Figure 8** (A-F) Acute hypersensitivity pneumonitis in a 65 year-old woman assigned to the padding wedded to puppets. HRCT scans of the lung at time of diagnosis (A-D) show an irregular patchy paving pattern more pronounced in lower lobes. Alterations have largely regressed after steroid therapy (E, F).



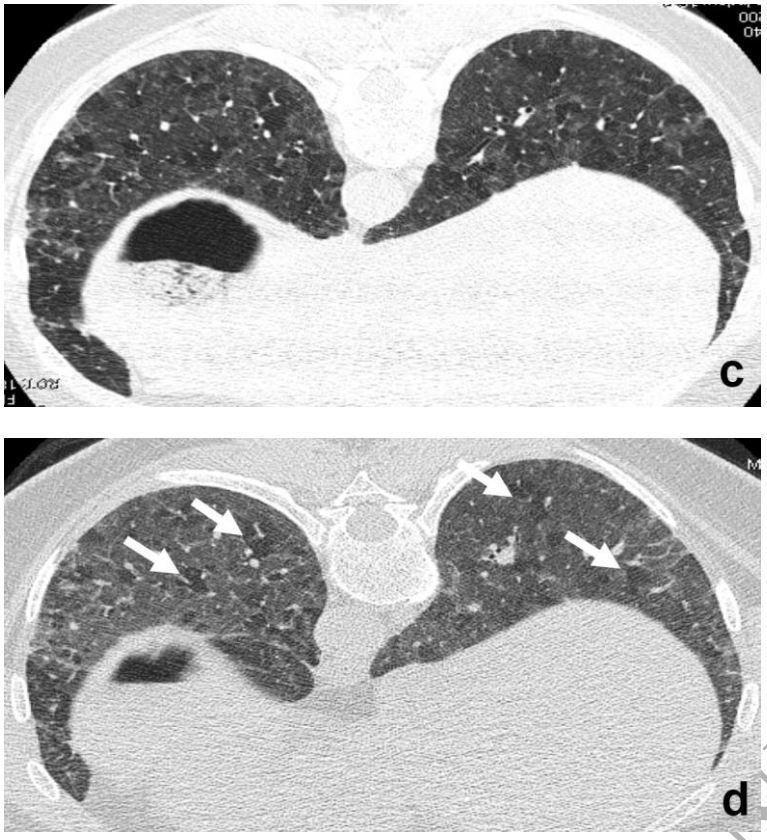
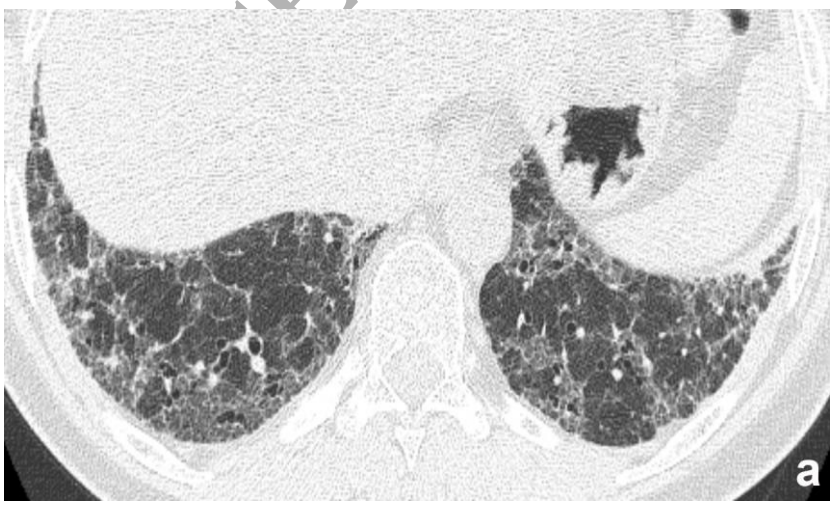
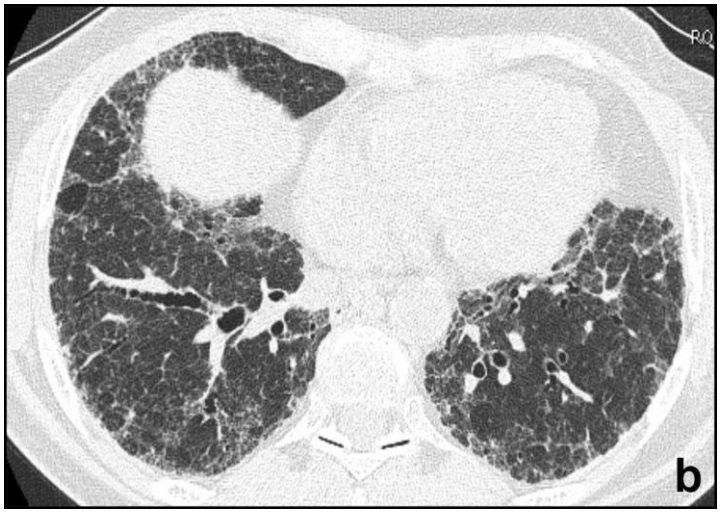
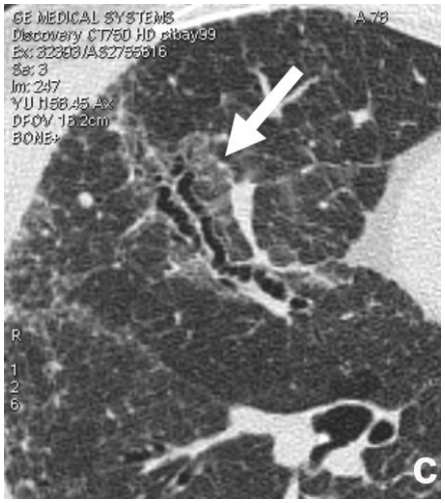
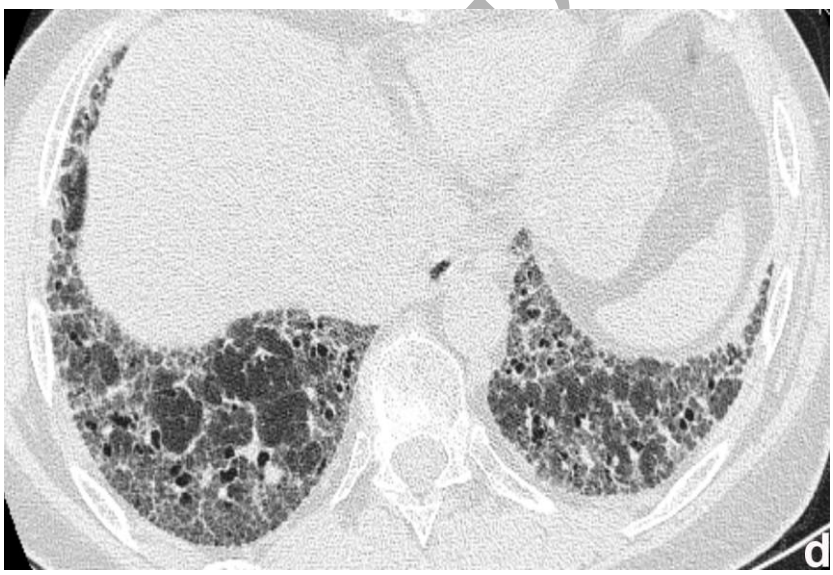


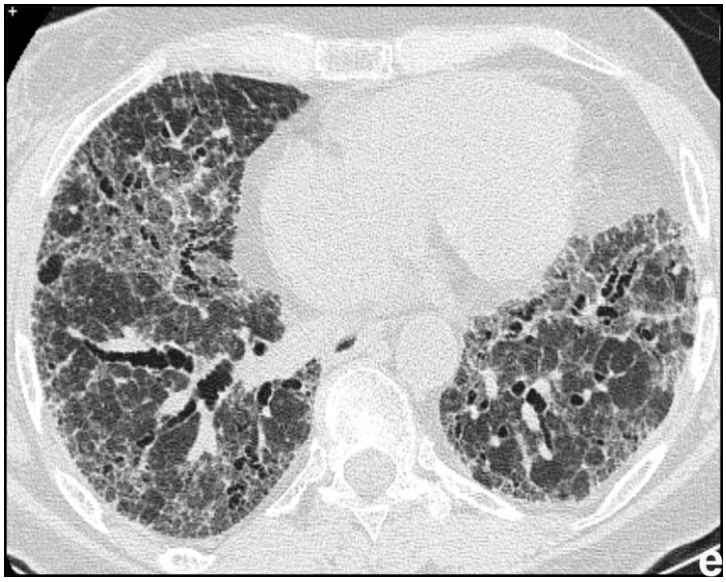

**Figure 9** (A-D) A 51 year-old woman with cough and dyspnea underwent a HRCT in May 2017 (A, B); the scans showed an extensive parenchymal ground-glass with interlobular septal thickening that was misinterpreted as pulmonary oedema. The exam was repeated, accompanied by an expiration scan in January 2018 (C, D), because of worsening symptoms and showed a lobular air-trapping pattern (arrows in D). An accurate clinical history of the patient revealed lung exposure due to patient's employment in cheese production. HRCT findings and work history were consistent with subacute OHP. This case demonstrates the importance of in depth knowledge and expertise of both the radiologist and the clinician to arrive at the correct diagnosis.







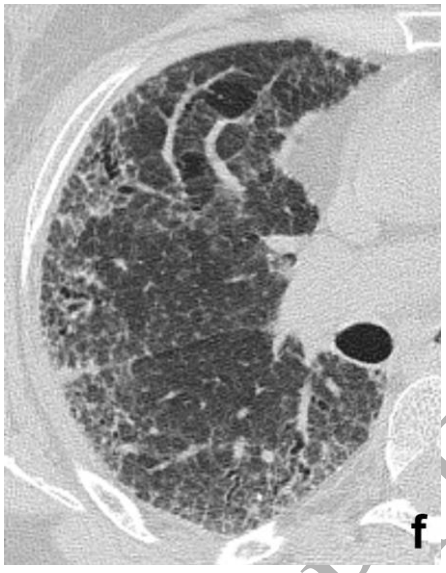
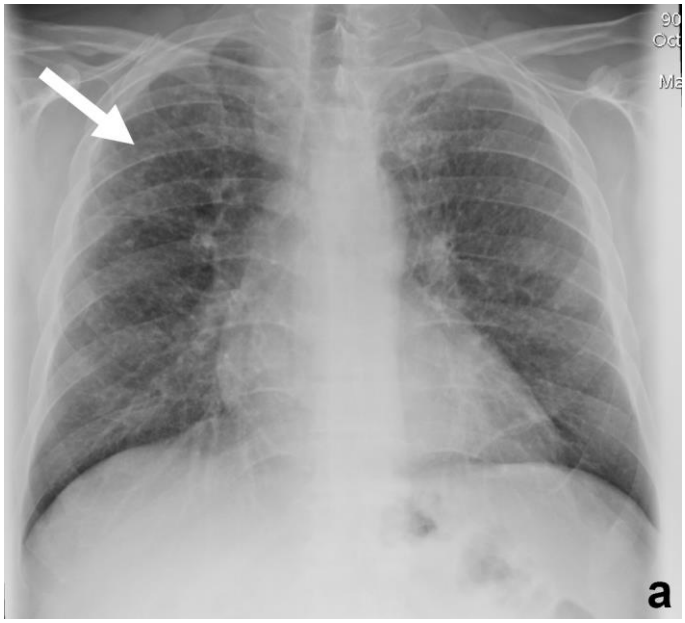


**Figure 10** (A-F) Chronic hypersensitivity pneumonia in a 63 year-old farmer. HRCT scans in April 2015 (A-C) show a reticular fibrotic pattern mostly distributed along bronchovascular bundles (arrow in C), with traction bronchiectasis and without significant craniocaudal gradient. Fibrosis worsened in October 2016 (D-F).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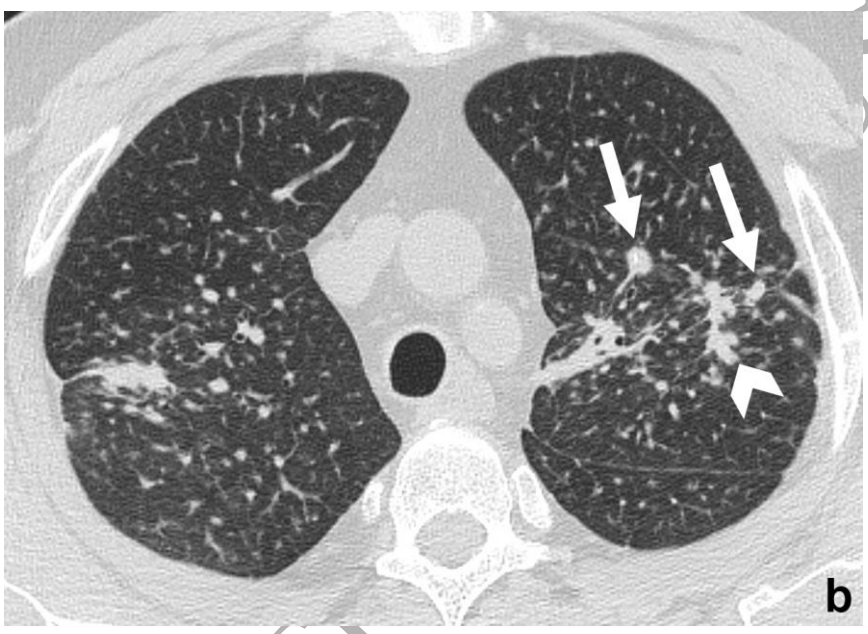
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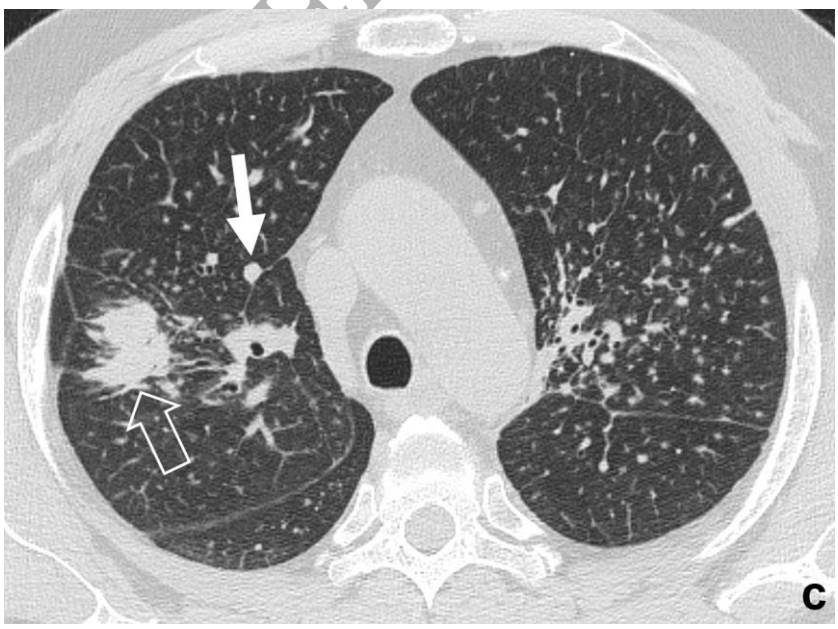
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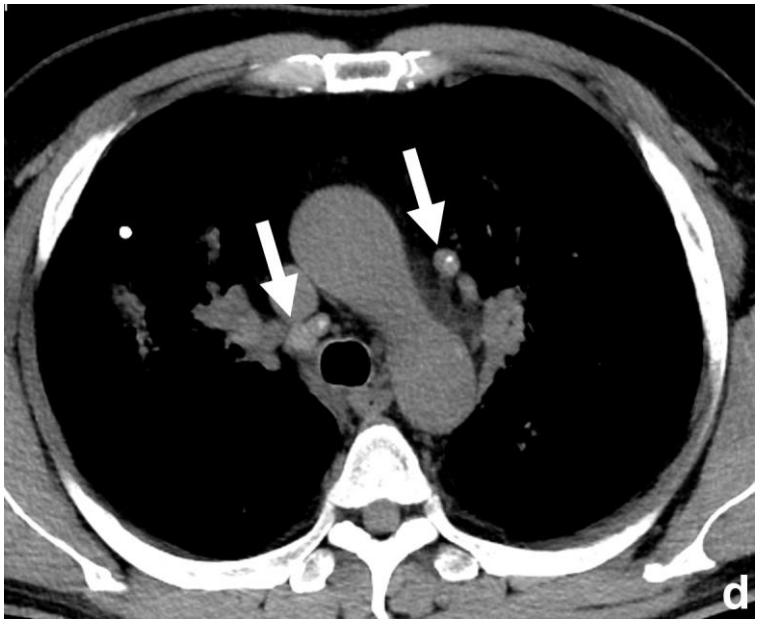


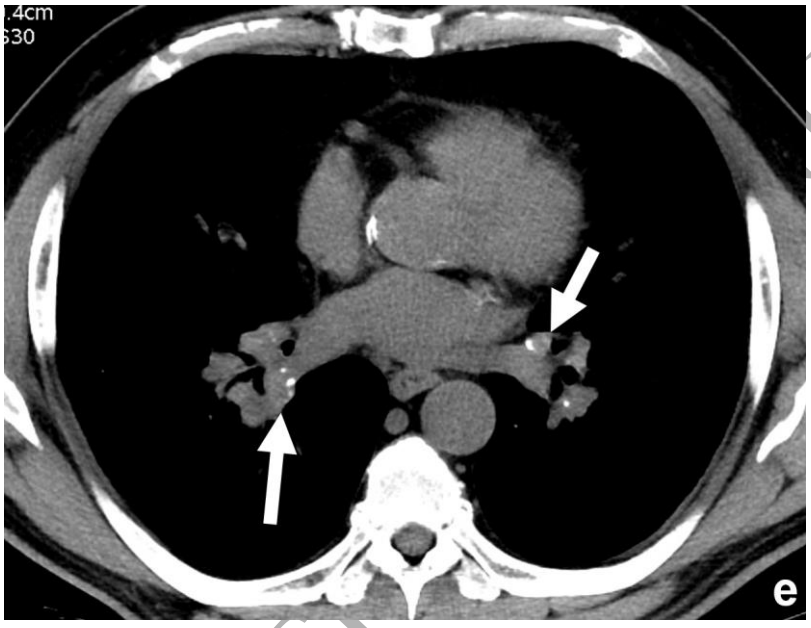
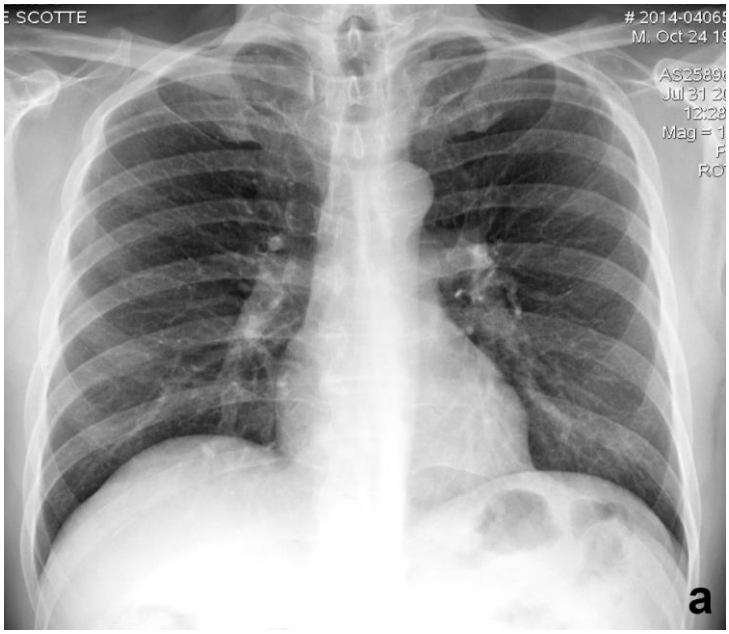
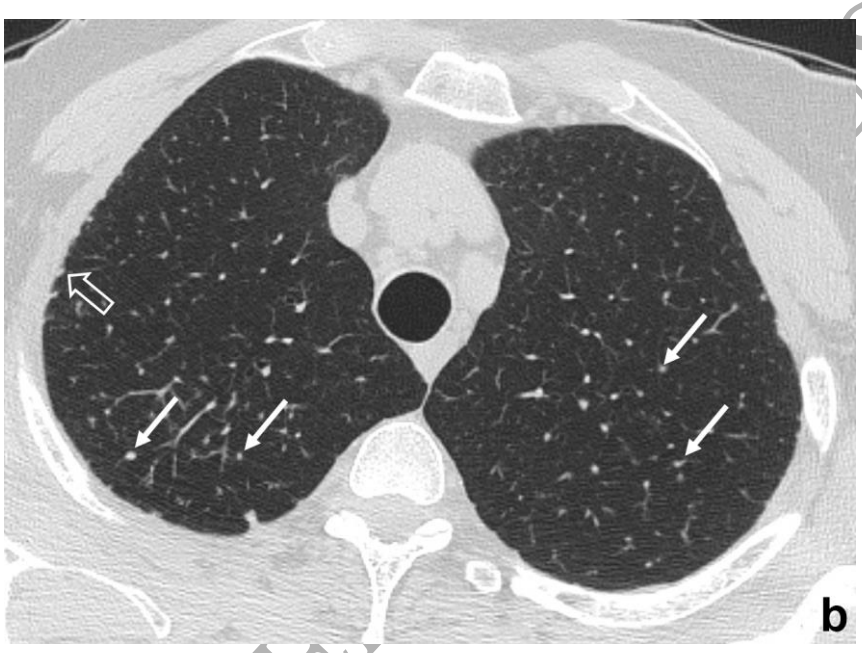




**Figure 11** (A-E) Silicosis in a 64 year-old man who has been employed for more than 15 years in the construction, maintenance and demolition of refractory ovens. Plain radiograph (A) shows multiple nodules (arrows in A) predominantly distributed in the upper pulmonary lobes. HRCT scans confirm numerous pulmonary nodules (arrows in B and C), sometimes coalescent (arrowhead in B), and conglomerate masses, irregular in shape (empty arrow in C). Moreover there are typical calcified mediastinal and hilar lymph nodes (arrows in D and E).



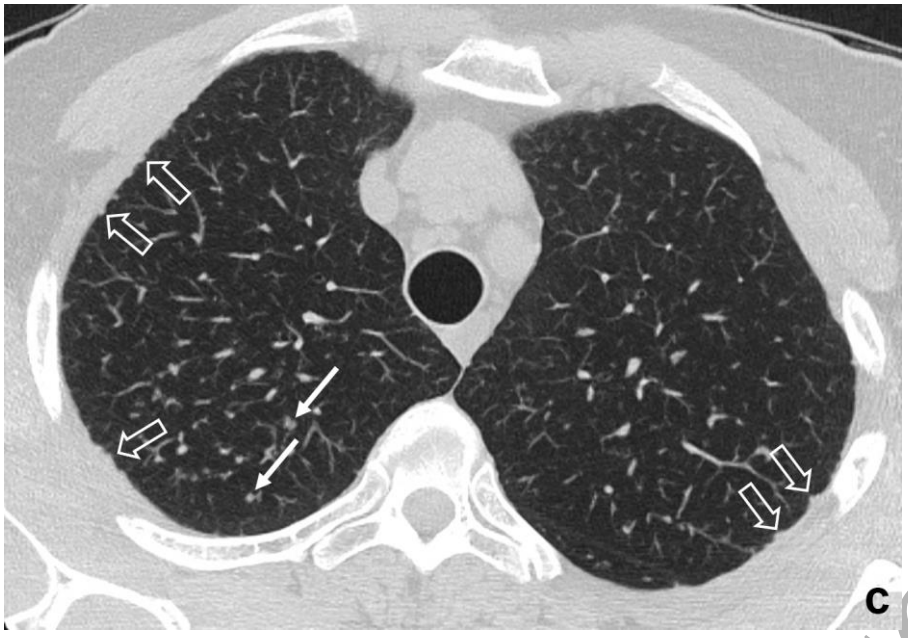
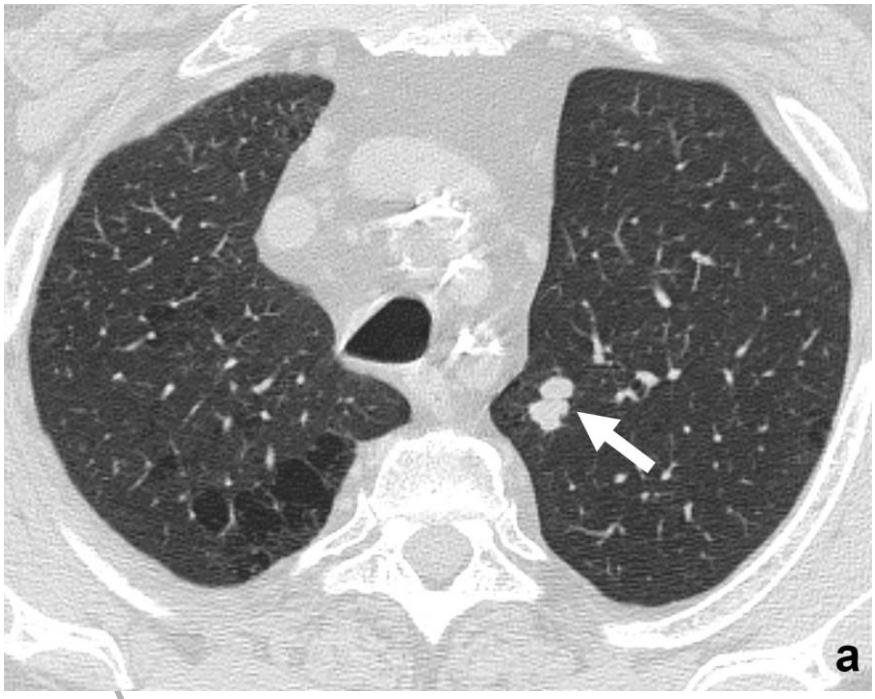



**Figure 12** (A-C) Silicosis in a 58 year-old man exposed to crystalline silica dust. Chest x-ray (A) is unremarkable. HRCT scans (B-C) show micronodules with upper lobe and posterior predominance (arrows) and pleural pseudoplaques formed by coalescent nodules (empty arrows).



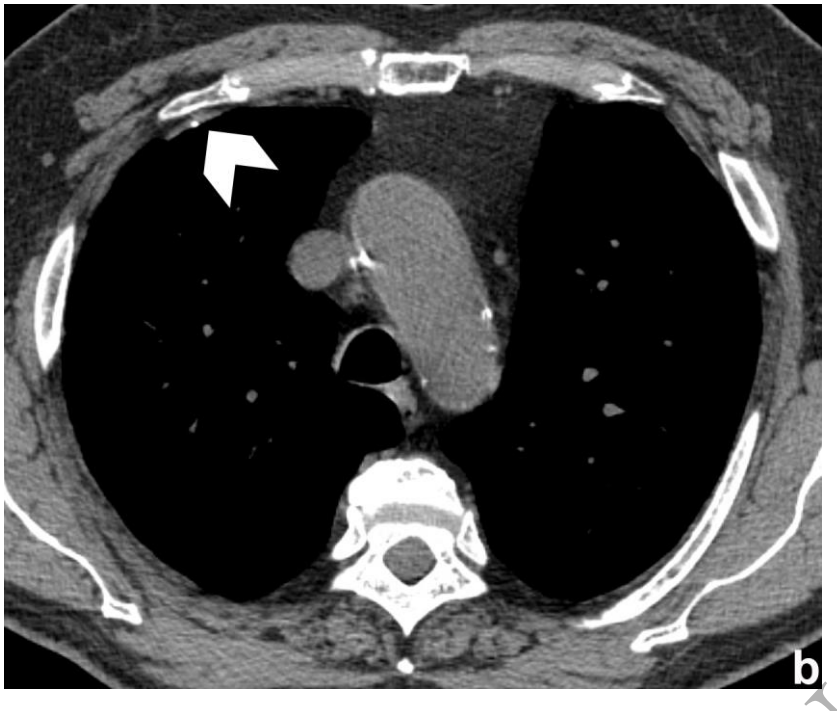
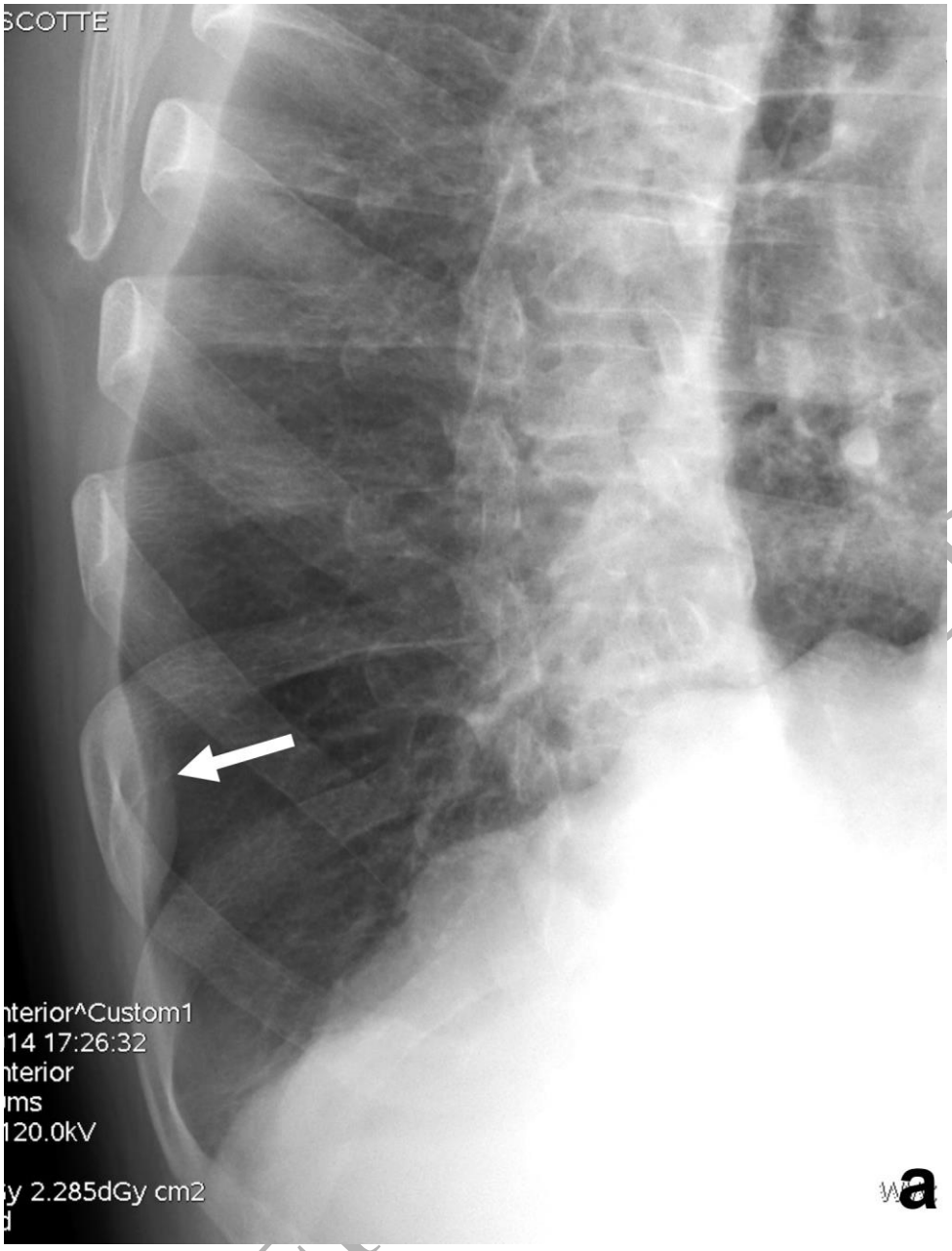



**Figure 13** (A, B) Peripheral adenocarcinoma (arrow in A) in a patient with asbestos-related pleural plaques (arrowhead in B).



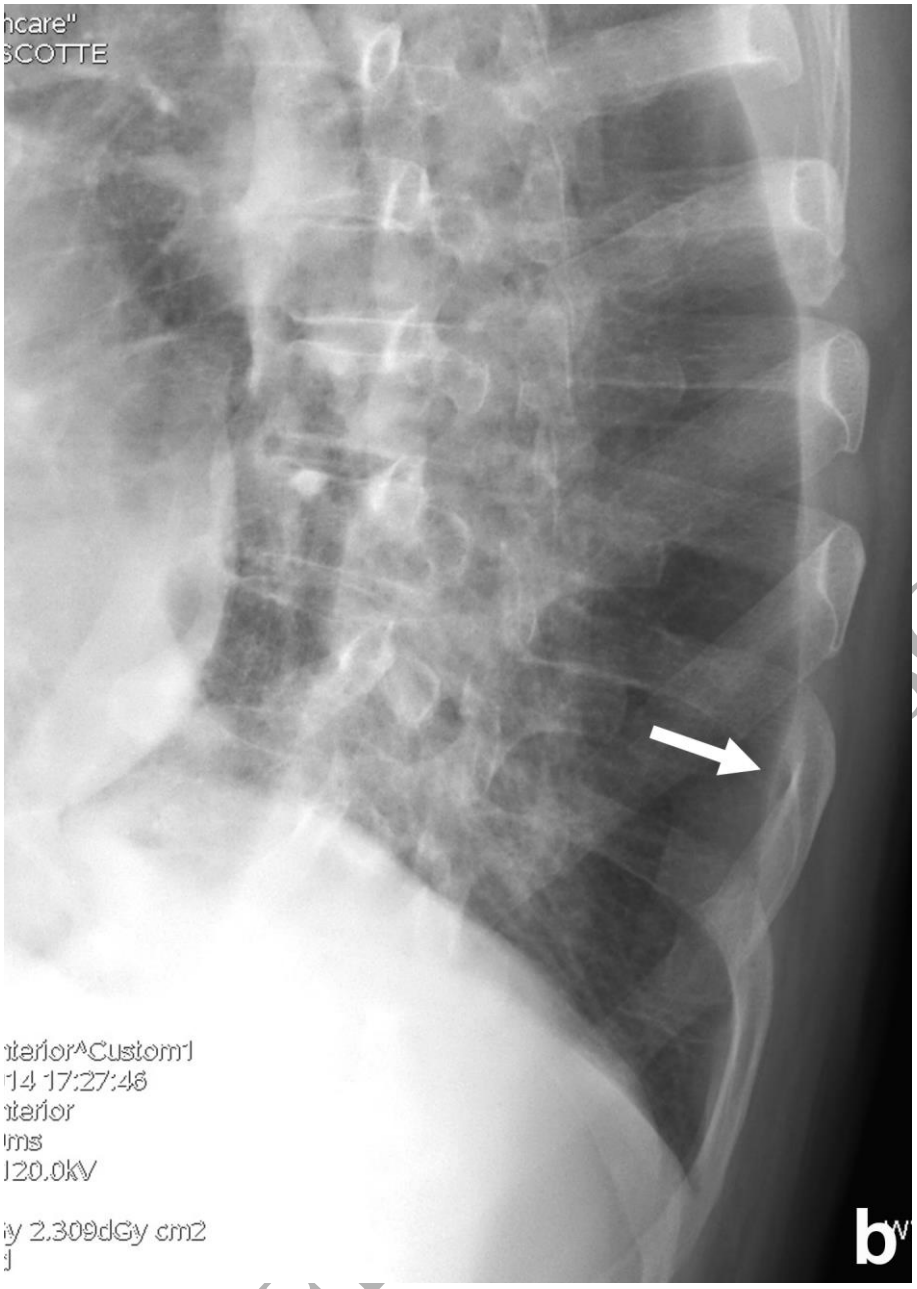



**Figure 14** (A, B) Oblique chest radiographs improve the possibility of identifying pleural plaques (arrows) on traditional radiology.

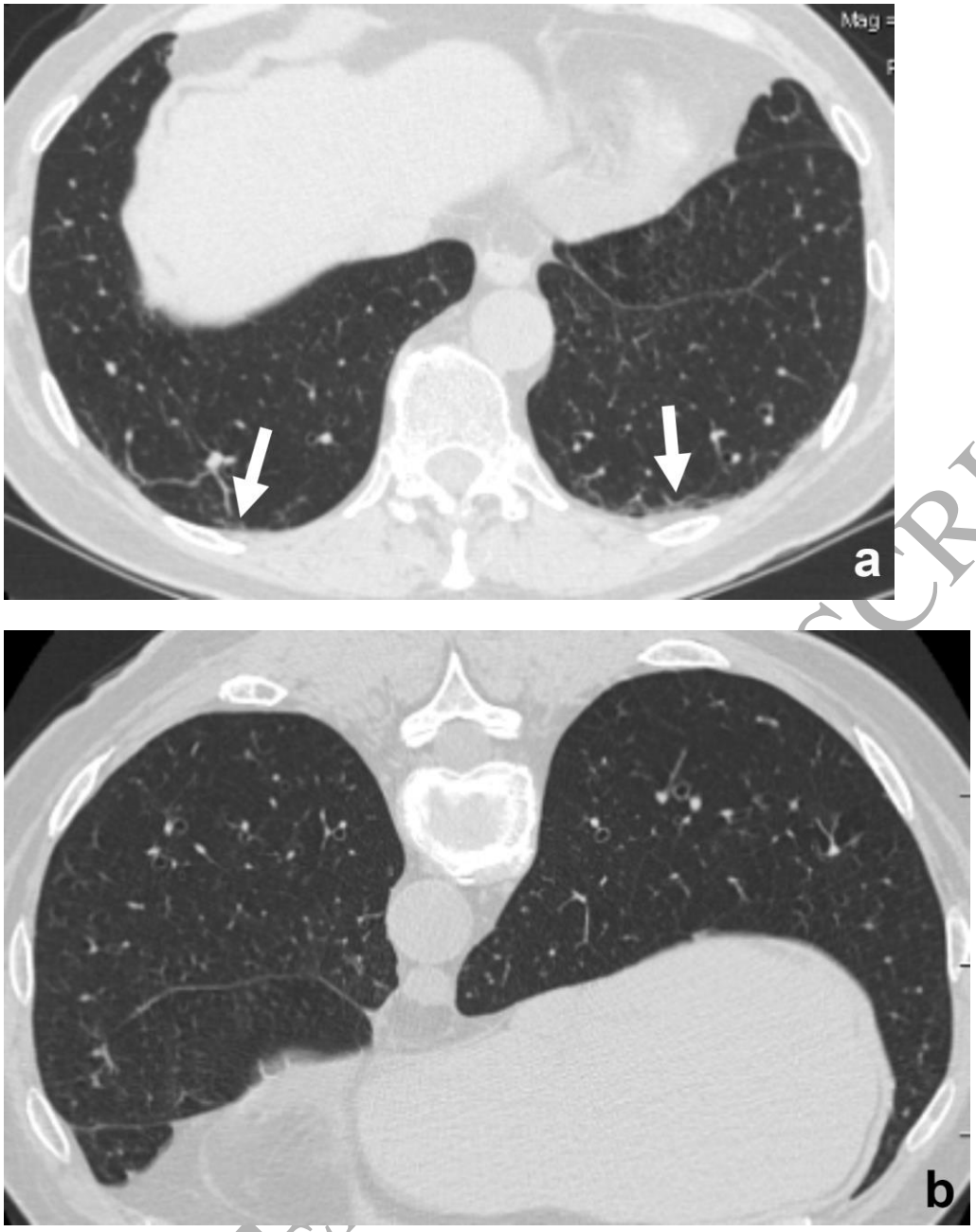
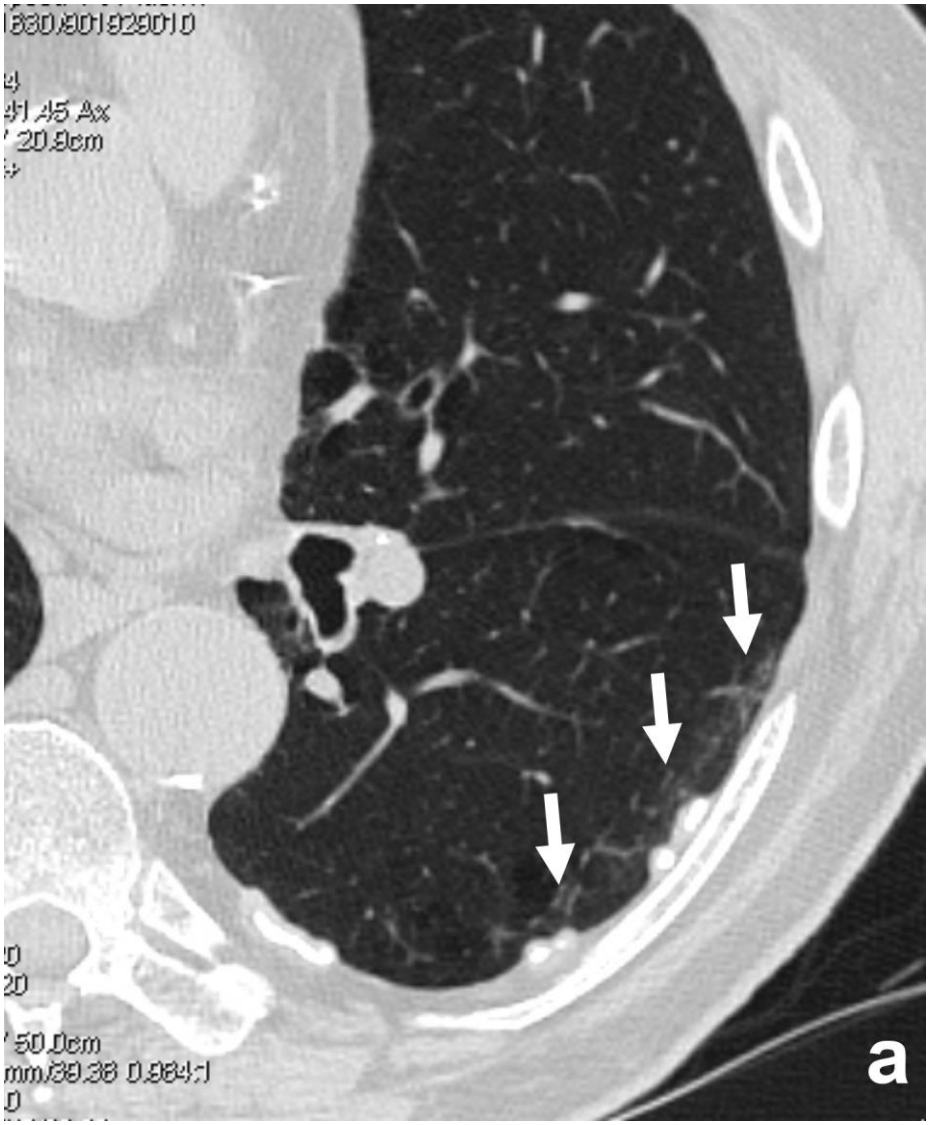



**Figure 15** (A, B) Dependent opacities (arrows in A) in a HRCT scan with the patient in the supine position, that simulate pulmonary fibrosis; the scan of the same patient in the prone position (B) clearly demonstrates the absence of pathological alterations.



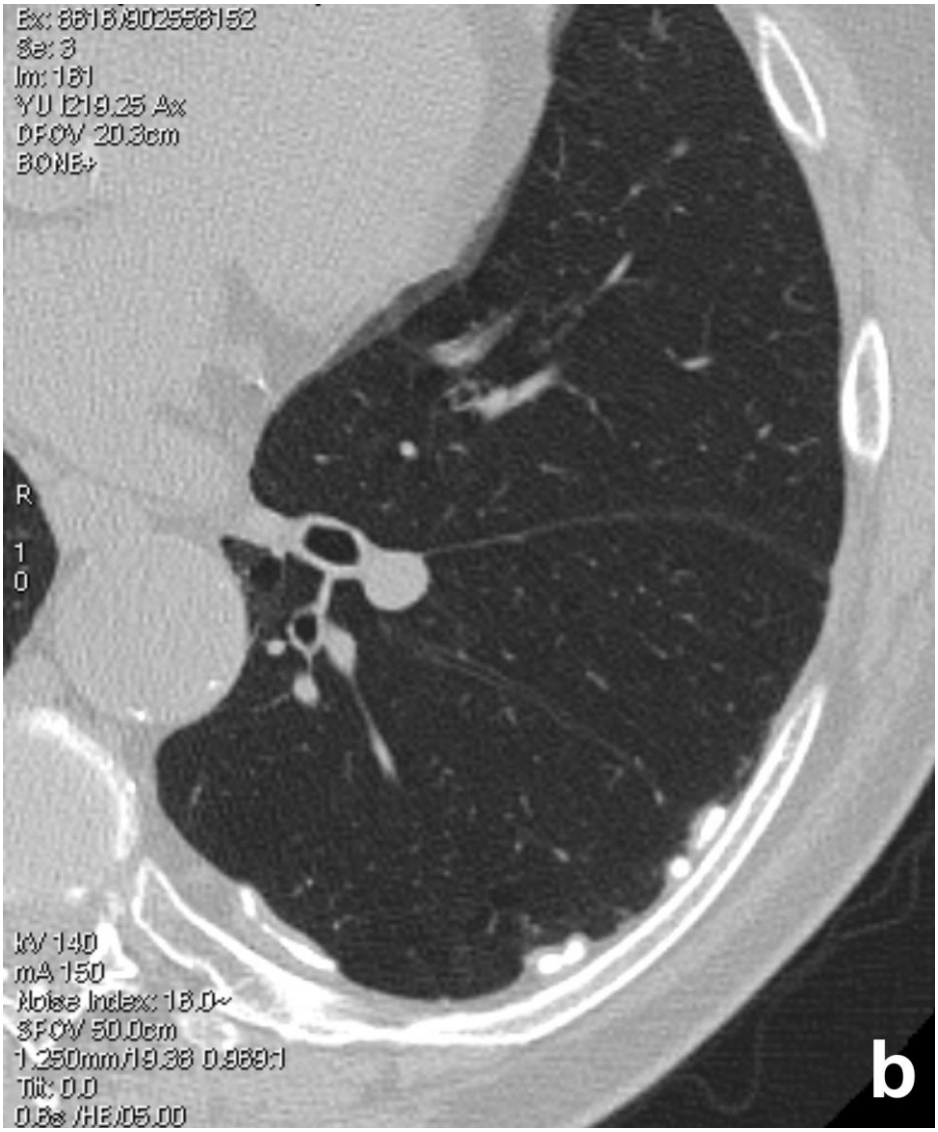
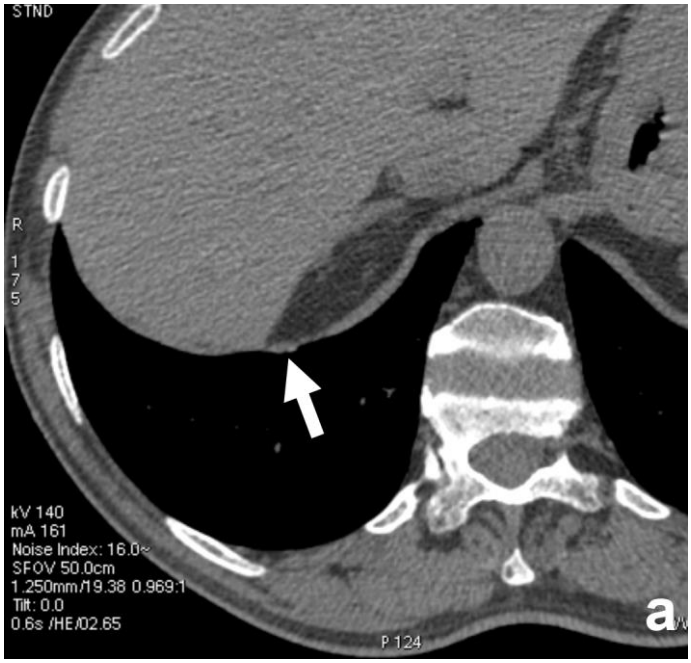



**Figure 16** (A, B) HRCT scans in an 84 year-old man with previous asbestos exposure and calcified pleural plaques (arrows). In 2009 (A) the exam was performed with the patient in the supine position and opacities next to the pleural plaques were reported as asbestosis by ad radiologist. In 2013 (B) the exam was performed with the patient in the prone position and demonstrated that previous lung alterations were consistent with dependent opacities.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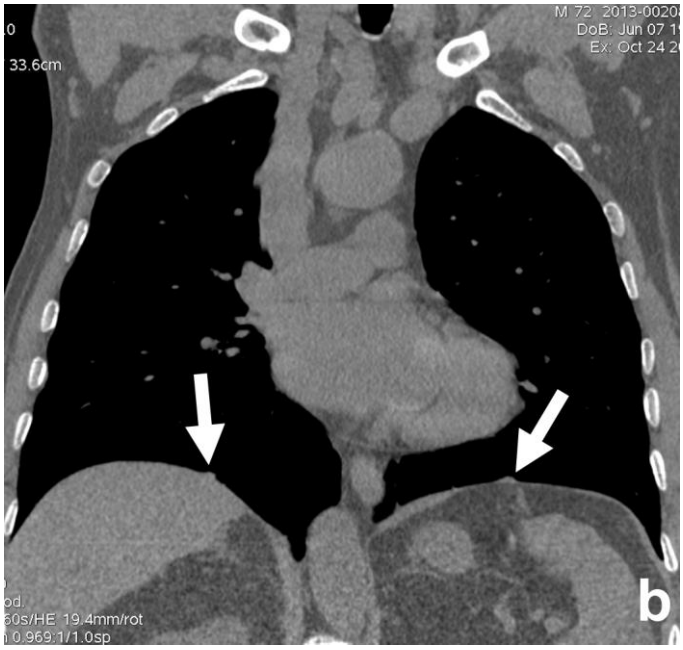
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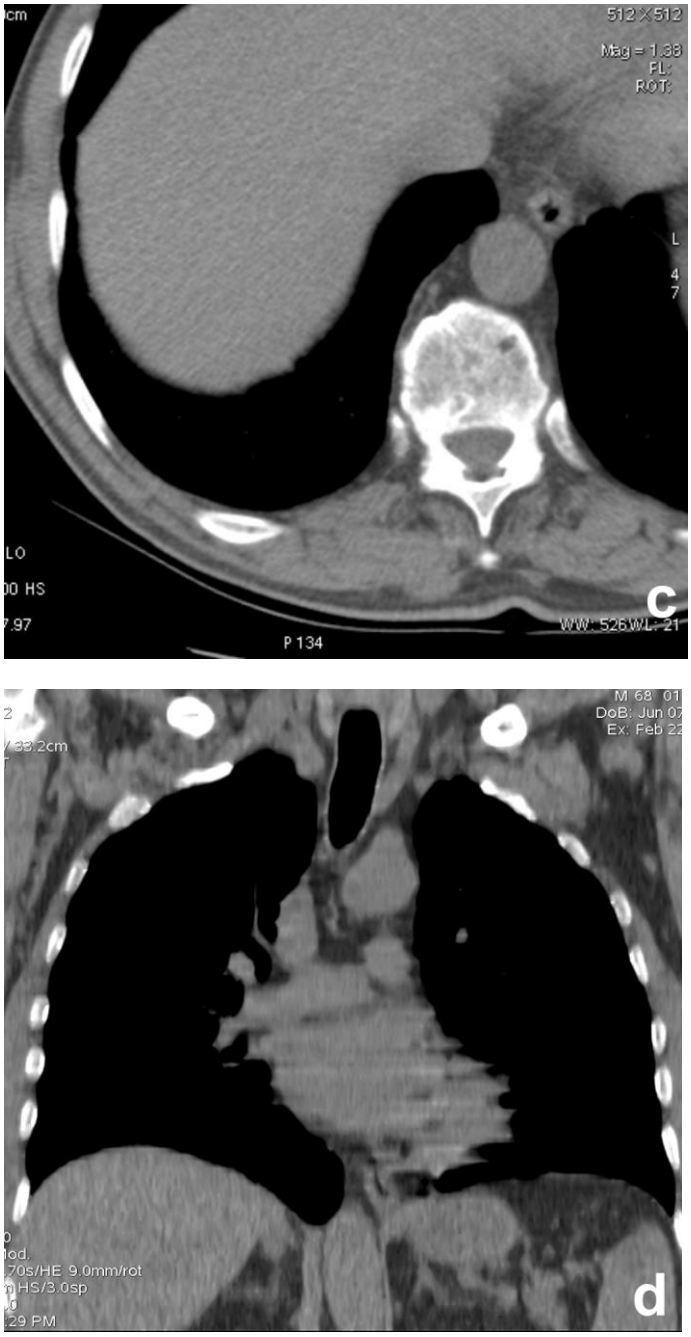
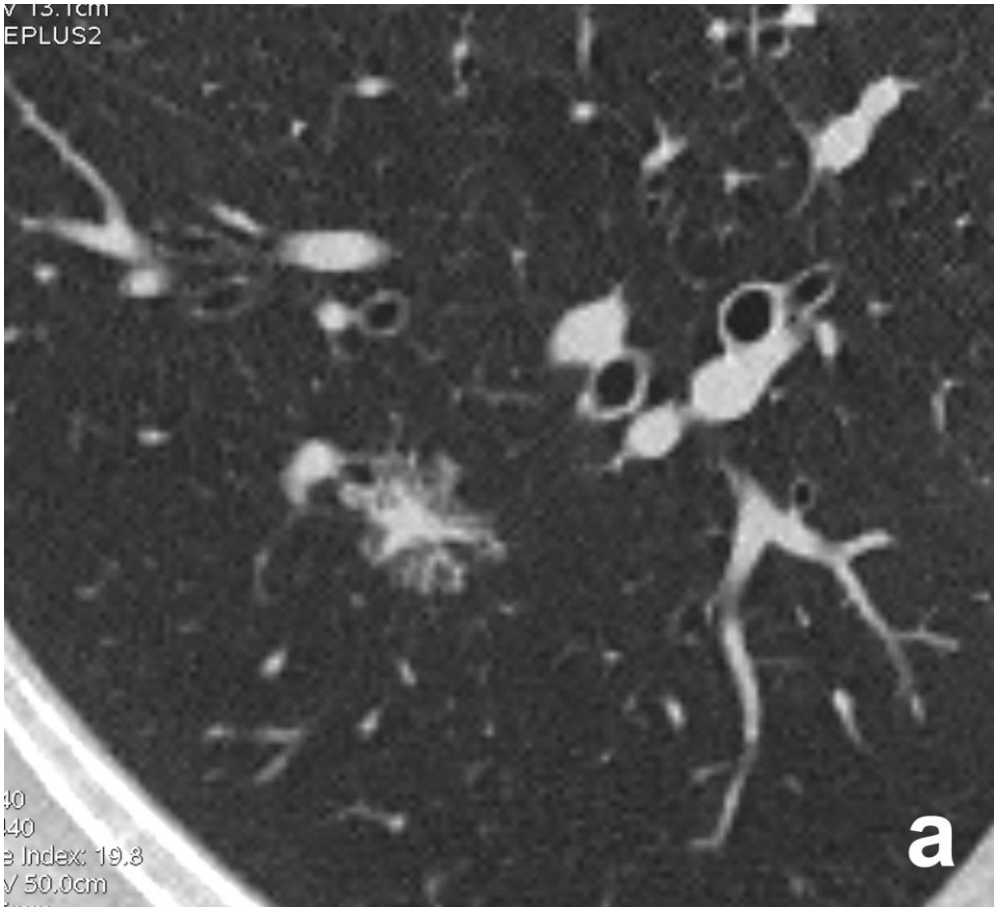



**Figure 17** (A-D) Comparison between two CT exams with different technical parameters of the same patient with asbestos-related pleural plaques; the first (A, B), correctly performed with an effective slice thickness of 1.25 mm and a reconstruction interval of 0.6 mm, depicted pleural plaques (arrows in A and B) whereas in the next exam (slice thickness of 3.00 mm and reconstruction interval of 3.00 mm) pleural plaques are not identifiable (C,D).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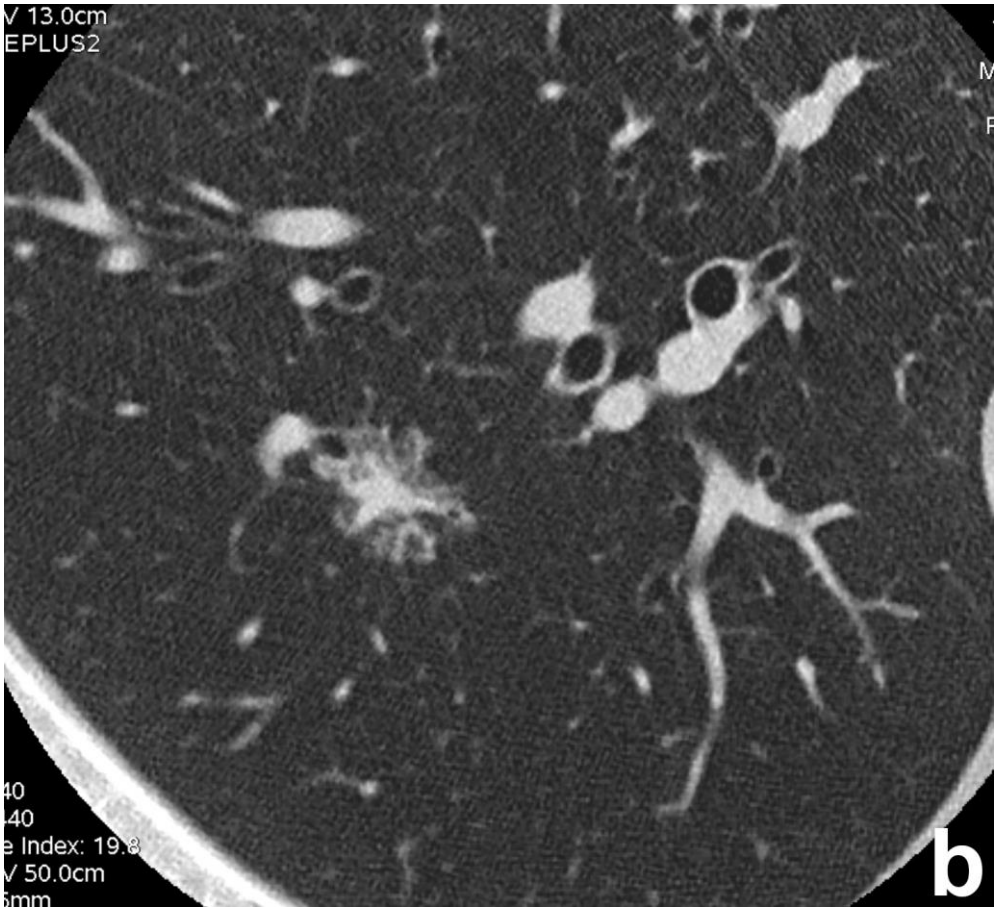
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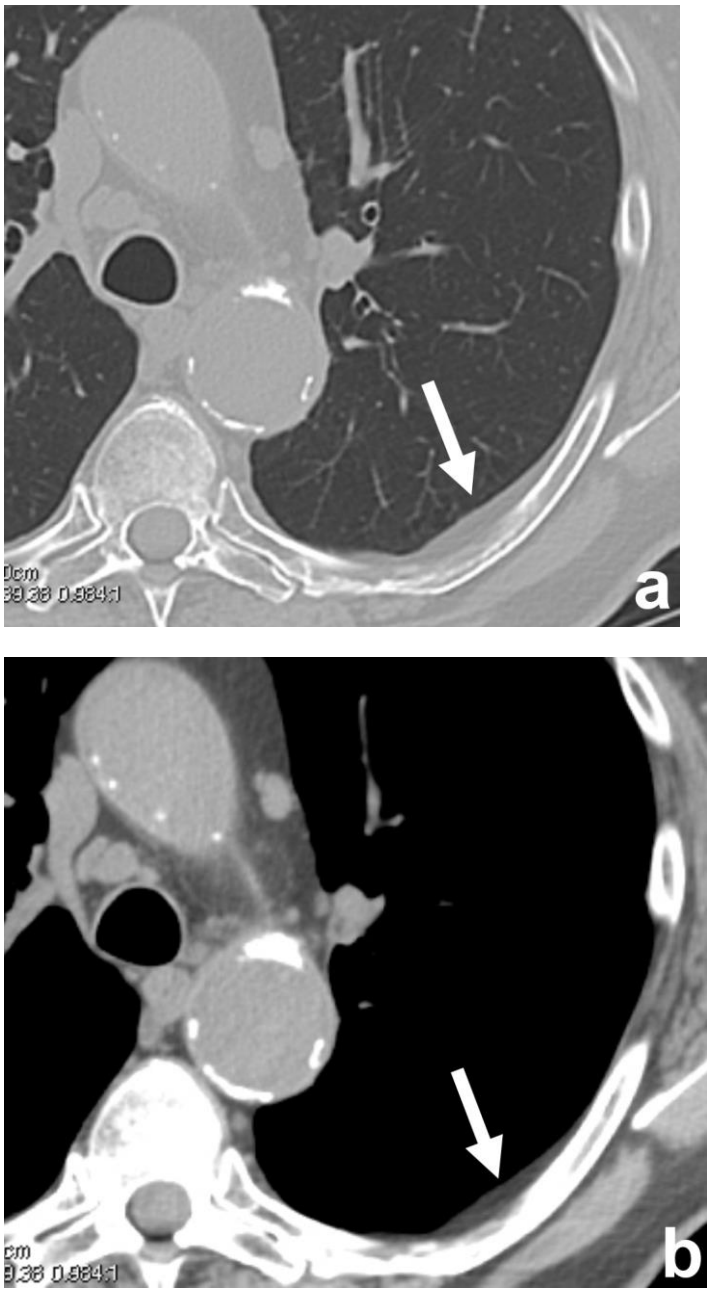
50.0cm
b

**Figure 18** (A, B) Comparison of spatial resolution between a spiral CT scan (A) with a slice thickness of 1.25 mm, a reconstruction interval of 0.6 mm, a scan FOV of 36 cm and an axial scan (B) with a slice thickness of 0.625 mm and a scan FOV of 10 cm. Borders of the pulmonary lesion are clearly more defined on the axial scan (B) than in the spiral one (A).



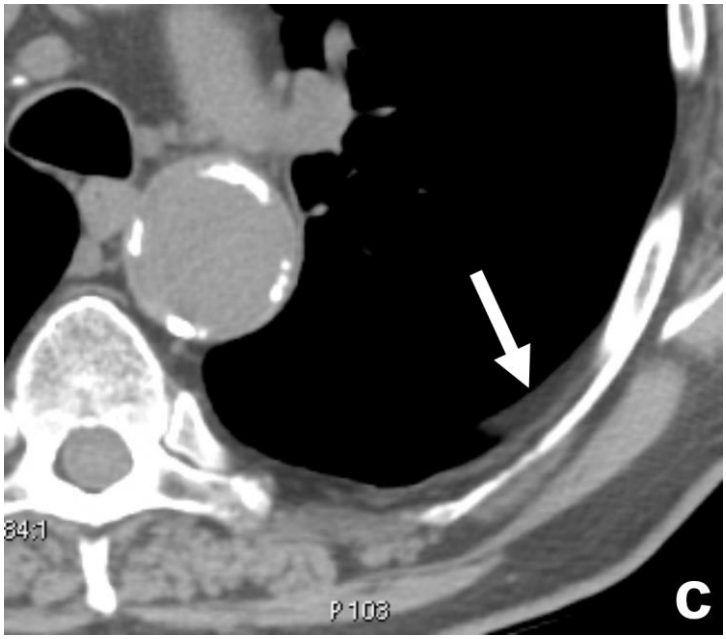
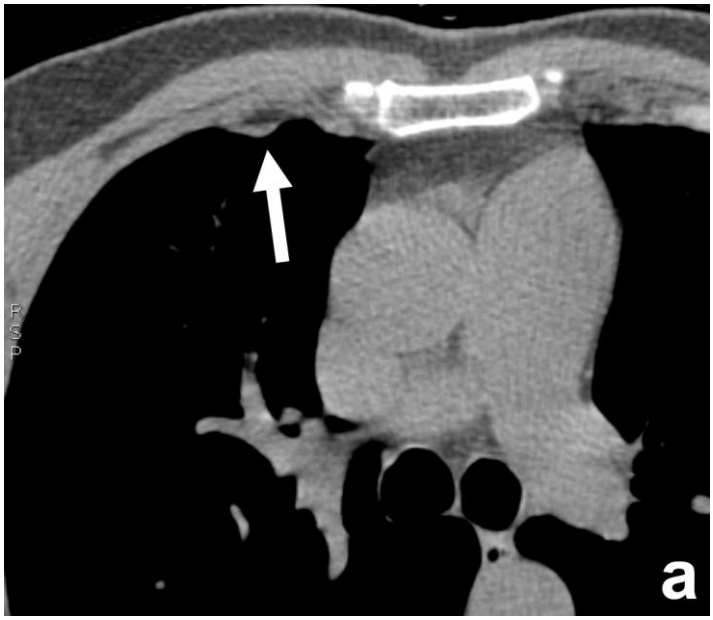



**Figure 19** (A-C) Normal extrapleural fat (arrows) that simulates a pleural plaque.



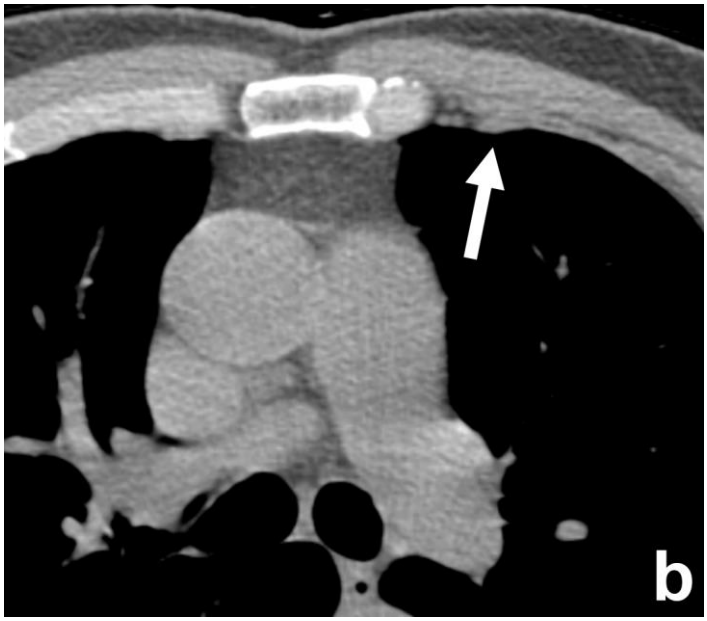



**Figure 20** (A, B) Transversus thoracic muscle (arrows) that simulates pleural plaques.

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