Silicosis, radiological findings in Chest radiograph and MDCT

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Learning objectives

- Describe the different radiological findings (X-Rays and MDCT) in the following types of classic silicosis
  - Simple
  - Complicated
- Outline the indications, advantages and limits of imaging techniques including X-Rays and MDCT.

Background

Silicosis is an occupational lung disease resulting from silica dust particles inhalation, also known as silica or silicon dioxide in crystalline forms. Crystalline forms can be found as quartz but also as cristobalite and tridymite. Free silica particles are the crystalline forms, and must be distinguished from silicates.

Once a worker has been exposed to the silica dust particles, no matter if it was for a brief period of time or a long exposure, these particles tend to accumulate in the lung, and create delayed development of fibrosis with progressive pulmonary dysfunction even years after the exposure has ceased. It has been reported acute silicosis in sandblasting workers, who develops rapid clinical silicosis called silicoproteinosis, that we discuss later. Silica particles produce Macrophages and other inflammatory/immune cells activation, producing several cytokines and chemokines, which can generate destruction of surrounding tissue and have shown to play an important role during the early inflammatory response after exposure.

Silica crystals are an abundant component on Earth's crust. Silicon dioxide (SiO2) has been found in many rocks such as marble, sandstone, flint and slate. Occupational exposure to breathable silica particles (0.5-5 microns in aerodynamic diameter) can be associated with several activities like mining, tunneling, etc.

Silicosis is well known as the oldest occupational disease, also called the widow-maker disease, reporting thousands of deaths each year. The prevalence has decreased compared with past decades, however nowadays, is often an unrecognized and underreported disease.

Epidemiology
High exposure to elevated concentrations of silica dust particles, silicon dioxide (SiO2), associates with risk occupations like: mining (heavy metal miners and rock miners), tunneling, drilling, denim jeans sandblasters, quarry, cement and concrete working, highway repair, ceramics and foundry, grinders, stone cutters, refractory brick workers, tombstone workers, pottery workers, dental laboratories and in rare occasions the exposure to diatoms. Diatoms develops a rare form of silicosis, white dust product of fossilize unicellular aquatic plants (diatoms), used in nail polishes, insecticides and varnishes manufacturing.

When a worker is exposed to silica particles with a diameter between 0.5-5 μm, has more probability to develop silicosis, instead of exposure to larger particles (>5.0 μm). Particles larger than 5.0 μm are expelled with cough or mucous secretion with the help of cilia movement, preventing its accumulation in lung alveoli. Although particles of silica with a diameter between 5-10 μm have shown in studies to present more concentration of silica than smaller particles.

Pathogenesis

Although silicosis is not quite yet fully understood, some believe that alveolar macrophages have an important role in the evolution of this disease. The severity of each case is related to the intensity of exposure to silica dust particles and associated with freshly cut or fractured silica.

The release of cytokines and other inflammatory mediators produced by neutrophils activation, lymphocytes and alveolar macrophages are the key for developing pulmonary changes secondary to silica dust particles. Fibroblasts also play an important role generating stimulating factors, creating hyalinization and collagen deposition.

The pathological lesion of a silicotic nodule is a central acellular zone with silica particles surrounded by collagen, active macrophages, fibroblasts and plasma cells. The dust particles are carried to the nearest lymphatics or can be transported through the bronquioles by the mucocilliar system. The silica particle is very cytotoxic to the macrophages, inducing death. Dead macrophages form massive fibrosis by releasing oxidants, cytokines and fibloblast proliferation agents, creating nodules.

Nodules tend to be in upper posterior lobes, close to bronquioles, small vessels and lymphatics. The macrophages loaded with silica particles tend to migrate to hiliar and mediastinal lymphatic nodes, generating a granulomatous like inflammatory process.
This tend to calcify generating the "egg shell sign" on plain chest radiographs, known as a pathognomonic sign of silicosis. As the disease progress, nodules tend to coalescence into big masses and migrate to the hilum leaving emphysematous tissue behind.

**Imaging findings OR Procedure details**

Silicosis is classified into two clinical forms: acute silicosis and classic silicosis.

**Acute silicosis**

Acute silicosis or silicoproteinosis, is an entity describe by an acute exposure to silica dust particles, in an occupation with a high exposure to fresh fractured silica in a unventilated environment. This may develop within a few months up to 5 years after the exposure. This result in a filling of the airspace in the lung with proteinaceous material. This entity can be confused with alveolar proteinosis.

Chest X-Ray findings:
- Large bilateral perihiliar consolidation or ground glass opacities.

CT findings:
- Bilateral nodular/ground-glass opacities with a centrilobular distribution.
- Multifocal patchy ground glass opacities
- Consolidation
- Crazy-paving appearance: characterize by diffuse ground-glass attenuation with interlobular septal thickening and intralobular lines that resembles a pavement street.

**Classic silicosis**

Classic or chronic silicosis differs completely from the acute form because it occurs in a low dose exposure in the working environment, within 15 or more years after exposure. Classic silicosis is classified into two radiological forms: Simple silicosis and complicated (progressive massive fibrosis PMF).

**Simple silicosis**
Chest X-Ray findings:

- Multiple nodular bilateral opacities mostly located in upper/posterior portion of the lungs.
- Multiple pulmonary nodules between 1-10 mm in diameter.
- Well-defined and uniform in shape nodules without calcifying.
- Reticular pattern that can be preceded or accompanied the multiple pulmonary nodules. Sometimes the reticular pattern is the first radiological manifestation, as well as A and B kerley lines can be present in patients with a clinical manifestation of the disease.

![Fig. 1](image)

**Fig. 1:** 69 year old male patient, with a history of working in cement and concrete during 25 years, with no medical history of chronic diseases. Patient was admitted through the emergency room with an acute shortness of breath associated with cough and fever. Chest x-ray showed bilateral micronodular pattern, mostly located in upper lobes and posterior segments as a result of simple silicotic nodules.

**References:** RADIOLOGY, HOSPITAL CLINICO UNIVERSITARIO LOZANO BLESA - ZARAGOZA/ES

CT findings:

- Multiple small nodules 2-5 mm in diameter.
- Better sharply defined nodules compared with coal worker pneumoconiosis disease.
- Nodules usually observed in upper/posterior lobes and perihiliary located in centrilobular, paraseptal and subpleural regions with a perilymphatic distribution.
- Subpleural regions may have a triangular configuration, and if they are confluent may resemble pleural plaques.
• It is frequent the presence of focal emphysematous parenchyma surrounding the nodule, centrilobular focal emphysema.
• Nodules can be calcified.
• Hilar and mediastinal lymph nodes can precede the parenchymal lesions. Calcification in the periphery and the eggshell calcification pattern can be highly suggestive of silicosis.

**Fig. 2:** Same patient shown in Fig.-1 with a CT imaging. Fig.-2A (left): CT of upper segments of the lungs with a mediastinal window shows the multiple nodules between 1-5 mm in diameter with some nodules that coalescence in the periphery with typical subpleural triangular shape. Fig. 2B (right): CT of upper segments with a lung window shows the same multiple nodules located in centrilobular, paraseptal and subpleural regions with a perilymphatic distribution. Interstitial septum's thickening resembling a reticular pattern can also been seen in this patient as a result of simple silicotic disease.

**References:** RADIOLOGY, HOSPITAL CLINICO UNIVERSITARIO LOZANO BLESA - ZARAGOZA/ES

Complicated form or progressive massive fibrosis (PMF)

It develops by the expansion and confluence of individual nodules. The confluence of individual nodules creates large opacities larger than 1 cm with irregular margins. These opacities gradually migrate centrally to the hilum, leaving emphysematous parenchyma behind. This complicated form is the final stage of silicosis.

Chest X-rays findings:

• Large symmetric bilateral opacities diameter > 1 cm.
• Often at the beginning the mass has a round or oval shape with a lateral edge well defined that is parallel to lateral chest wall. Then the mass tend to have irregular margins
- Commonly observed middle lung zone, perihilar.
- Emphysematous, fibrotic tissue and pleural plates as a residual process.

**Fig. 4**: 75-year-old male patient with an exposure of silica dust particles in drilling and mining for approximately 25-30 years. Simple chest X-ray (frontal and lateral view) shows large bilateral perihilar masses located in middle lung with irregular dull edges, multiple large mediastinal lymph nodes with eggshell calcification and fibrotic parenchymal changes in upper lobes.

**References**: RADIOLOGY, HOSPITAL CLINICO UNIVERSITARIO LOZANO BLESA - ZARAGOZA/ES

**CT findings**:

- Large focal masses with irregular dull margins and punctate calcification, surrounded by emphysematous tissue.
- Cavitation secondary to ischemic necrosis may occur in a mass larger than 5 cm.
- Distortion of the pulmonary architecture and vessel distribution.
- Large mediastinal and perihiliar nodes, only 15-38 % are visible and in rare occasions (<5%) eggshell calcification pattern can be visualized.
**Fig. 5:** CT of same patient as Fig.-3. Right column (mediastinal window) and left column (lung window) shows large bilateral mediastinal lymph nodes calcified in the periphery resembling eggshell sign. Large hiliar and perihiliary bilateral masses, 5 cm approximately, with irregular dull margins and no low attenuation in central portions that suggest central necrosis. Interstitial septum's thickening as well as pleural thickening with fibrotic tissue surrounding the large masses can be seen also in this patient as a result in a complicated silicotic disease.

**References:** RADIOLOGY, HOSPITAL CLINICO UNIVERSITARIO LOZANO BLESA - ZARAGOZA/ES

Silicosis with mycobacteria disease

Patients diagnosed with silicosis has a higher risk (2.8 times more) to develop tuberculosis or other mycobacteria infections compared with normal patients. Pulmonary tuberculosis occurs in 25% of patients with acute or classic silicosis. Mycobacterial infection should be considered in silicosis diagnosed patients with acute pulmonary symptoms with rapid disease progression or asymmetric pulmonary opacity with or without cavitation. The risk of mycobacterial infection is higher in patients with acute silicosis rather than the classic silicosis.

CT vs. Simple Chest Radiography
Studies have shown higher detection of early silicotic findings as well as progressive massive fibrosis comparing CT vs. plain radiography. Many studies lean in favor of CT because it is more reproducible and accurate, with a better quality resolution imaging compared with chest x-ray. Superposition of opacities and nodules gives a disadvantage to plain radiography diagnosing early findings in patients exposed to silica dust particles. The majority of studies have positive results in the correlation between radiological and clinical findings; however, in various studies a low statistical significance has been shown regarding the comparison between CT and chest x-ray. Still the decision between the use of CT imaging or plain radiography is uncertain to determine.

**Images for this section:**

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Fig. 2: Same patient shown in Fig. 1 with a CT imaging. Fig. 2A (left): CT of upper segments of the lungs with a mediastinal window shows the multiple nodules between 1-5 mm in diameter with some nodules that coalesce in the periphery with typical subpleural triangular shape. Fig. 2B (right): CT of upper segments with a lung window shows the same multiple nodules located in centrilobular, paraseptal and subpleural regions with a perilymphatic distribution. Interstitial septum’s thickening resembling a reticular pattern can also been seen in this patient as a result of simple silicotic disease.

Fig. 3: 77 year old male patient, with mine working history and 30 years exposure. Diagnosed with silicosis 20 years ago by lung biopsy. Patient was admitted in the emergency room with increased on his dyspnea and fever. X-rays shows large bilateral perihilar opacities with irregular and dull margins as a result of the coalescence of pulmonary nodules. Emphysematous parenchyma, fibrotic tissue in upper portions of lobes and large mediastinal lymph nodes can also be observed in this patient with diagnosis of progressive massive fibrosis or complicated silicotic disease.
**Fig. 4:** 75-year-old male patient with an exposure of silica dust particles in drilling and mining for approximately 25-30 years. Simple chest X-ray (frontal and lateral view) shows large bilateral perihilar masses located in middle lung with irregular dull edges, multiple large mediastinal lymph nodes with eggshell calcification and fibrotic parenchymal changes in upper lobes.

**Fig. 5:** CT of same patient as Fig.-3. Right column (mediastinal window) and left column (lung window) shows large bilateral mediastinal lymph nodes calcified in the periphery resembling eggshell sign. Large hilar and perihilar bilateral masses, 5 cm approximately, with irregular dull margins and no low attenuation in central portions that...
suggest central necrosis. Interstitial septum's thickening as well as pleural thickening with fibrotic tissue surrounding the large masses can be seen also in this patient as a result in a complicated silicotic disease.

Fig. 6: Same patient as Fig. 4, MDCT with lung window (axial, coronal and parasagital views). Large bilateral perihilar masses with irregular dull margins and punctuate calcification surrounded with minimal emphysematous tissue. Distortion of pulmonary architecture and vessel distribution. Large calcified eggshell hiliar and mediastinal lymph nodes, and pleural plaques-like formations in upper lobes.

Fig. 7: Same patient as Fig. 4, Fig. 6. MDCT with mediastinal window (axial, coronal and sagital views). Large hiliar and mediastinal lymph nodes with eggshell calcifications. Large bilateral perihilar masses with punctate calcification with irregular dull margins.
Conclusion

Silicosis is an irreversible occupational disease that according to the time and quantity of exposure to silica dust particles can be divided into 2 main clinical presentations: acute (silicoproteinosis) and Classic (Chronic). Classic silicosis can also be divided into simple and a complicated form, which is the final stage of the natural history of this disease.

Chest x-rays gives accurate information to radiologists and other specialists regarding minimal parenchymal changes, to whether diagnose simple silicosis or complicated form. This allows early prevention of exposure to silica dust particles. However MDCT has a higher sensibility for detection of small parenchymal lesions located in upper/posterior portions of the lungs, but the cost of each MDCT diagnostic procedure is higher compared to plain chest x-ray.

Nevertheless if a patient has a history of exposure to silica with acute pulmonary symptoms and plain chest x-ray concludes no abnormal findings, a lung CT should be considered to rule out small silicotic nodules and prevent further exposure.

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**Personal Information**