Occupational Medicine Forum

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What are the Major Points and Emerging Issues in Radiologic Imaging for Pneumoconiosis Surveillance and Diagnosis?

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Although advances in radiologic imaging have facilitated the detection of disease, as well as the transmission and storage of images; diagnostic and surveillance guidelines for dust-exposed workers have not always kept pace with new technology. In particular, the International Labor Office (ILO) International Classification of Radiographs for Pneumoconioses (ILO/ICRP) was designed for the interpretation of analog radiographs.[1] Many hospitals no longer offer analog films, however, and now perform all plain films using digital imaging. In addition, clinicians must sometimes clinically correlate and explain to the exposed worker divergent findings from high-resolution computed tomography (HRCT) versus plain chest radiographs (CR). The following clinical vignette illustrates emerging challenges in pneumoconiosis surveillance and diagnosis. We then review the typical radiographic appearance of silicosis, mixed dust pneumoconiosis (MDP), and asbestosis; imaging guidelines for exposed workers; and test characteristics of current imaging methods.

Case Vignette

A 55-year-old sandblaster was seen for annual surveillance in September 2005. He reported a 20 pack-year smoking history (quitting 19 years previously), a history of chronic bronchitis, and childhood asthma. He had been sandblasting for 6 years with an abrasive containing aluminum, titanium oxide, and trace silica. Although he used an air-supplied helmet while sandblasting, contrary to procedure, he reported pouring and dry sweeping the abrasive without respiratory protection. For the preceding 25 years, he had been cutting and grinding metals.

Physical examination was remarkable for coarse bibasilar breath sounds. Spirometry demonstrated forced expiratory volume in one second (FEV_1) 2.3 L (72% predicted), forced vital capacity (FVC) 3.21 L (81% predicted), and FEV_1/FVC of 72%, indicating mild obstruction. A digital CR revealed mild diffuse reticular opacity throughout both lungs. Consistent with that interpretation, an independent B reading of the digital image identified small opacities in all six lung zones with 1/1 profusion and no pleural disease noted. He was referred for further evaluation, including HRCT of the chest taken 2 months later. The HRCT, however, showed no evidence of interstitial lung disease. The patient was informed of the latter test results indicating no pneumoconiosis. He was urged to continue respiratory precautions during blasting and to use a cartridge respirator while pouring and sweeping the abrasive.

Clinical and Radiographic Features of Silica, Mixed-Dust, and Asbestos Exposures

Although our worker probably did not have interstitial lung disease on the basis of the HRCT, crystalline silica in the abrasive places him at risk for silicosis, and his other exposures for MDP. Three clinical forms of silicosis have been defined: acute, accelerated, and chronic.[2] Acute silicosis may cause dyspnea and fever within weeks to 5 years of exposure to high concentrations of respirable silica. CR findings in acute silicosis include airspace filling correlating histologically with alveolar lipoproteinosis. Both CR and CT may demonstrate consolidation and centrilobular nodular or patchy ground-glass opacities bilaterally. Accelerated and chronic silicosis require longer latencies: 5 to 10 years of significant exposure; and at least 10 years of low-level exposure, respectively. Both are associated with interstitial reticulonodular opacities predominately in the upper to midzones and posteriorly. Simple silicosis is characterized by well-defined, small or round irregular opacities; on CT findings they may be centrilobular, paraseptal, or subpleural. Infrequently, progressive massive fibrosis (PMF) or complicated silicosis occurs, where individual nodules coalesce to form large, conglomerate lesions (one or more opacities greater than 1 cm in diameter).[2,3] Hilar node ("egg shell") calcification may be present, while cavitation suggests silicotuberculosis or ischemic changes in a silicofibrotic mass.

Mixed dust exposure commonly refers to a combination of crystalline silica and non-fibrous silicates, though definitions vary.[4] The latter generally contain silicon, oxygen, and one or more metals such as aluminum, beryllium, calcium, iron, magnesium, manganese, or potassium. Non-coal carbon particles may form a minor component of the dust. Histologically, MDP presents with dust macules or mixed-dust fibrotic nodules, with or without silicotic nodules. CR reveals irregular opacities with fewer of the small rounded opacities typical of silicosis. CT may demonstrate reticular, reticulolinear, or reticulonodular opacities often with emphysematous changes. Uncomplicated MDP generally follows a less severe course than silicosis, but rare cases may progress to end stage interstitial fibrosis. Symptoms are non-specific, and other interstitial diseases must be excluded for the diagnosis of MDP.

Among the conditions associated with asbestos exposure such as pleural plaques, mesothelioma, and lung cancer, "asbestosis" properly refers to parenchymal fibrosis. Typically, it is preceded by asbestos-related pleural findings and develops after a latency and exposure of 20 or more years. Common findings include irregular opacities with a fine reticular (linear) pattern and bilateral pleural thickening/plaques, which may calcify. Markings initially predominate at the bases and periphery with progression to mid and sometimes upper lung zones.[2,3] CT may detect inter- and intralobular thickening, pleural-based nodules, patchy ground-glass opacities, and small cystic spaces. CT may also detect changes early in the disease, while the CR is still normal. Late stage asbestosis is characterized by honeycombing in the peripheral and posterior lung areas.[2]

Radiography in Medical Surveillance

Occupational Safety and Health Administration (OSHA),[5,6] American College of Occupational and Environmental Medicine (ACOEM),[7] and World Health Organization (WHO)[8] guidelines for the use of radiographs in the medical surveillance of dust-exposed workers are summarized in Table 1. Under the ILO/ICRP, chest film interpretation entails side by side comparison of original analog, plain films to standard analog radiographs. This system defines opacities according to shape (irregular or rounded); size (large is more than 1 cm); and profusion on posterior-anterior chest radiographs in six lung zones. Opacities with profusion 1/0 or greater are considered consistent with pneumoconiosis. Pleural thickening is classified according to site, width, extent, and calcification. To reduce inter-reader variability, National Institute for Occupational Safety and Health (NIOSH) developed a certification examination for "B readers" to demonstrate proficiency in applying the ILO system.[9]

Among its shortcomings, however, the ILO/ICRP does not define specific disease entities, consider occupational history, or incorporate lateral and oblique views into the quantitative grading, though comments may be made regarding these imaging results. Furthermore, given that some institutions have begun to use only digital imaging methods, the need for analog films for ILO pneumoconiosis classification poses a new and currently unanswered challenge. Studies comparing digital and analog methods are currently limited. Because the ILO specifies that standard films take precedence in defining profusion categories, NIOSH continues to recommend analog originals and standards for those using the ILO/ICRP until full evaluation of the evidence for digital imaging is complete.[9] To reconcile current technological transitions with traditional surveillance standards, ACOEM recommends that NIOSH develop protocols for soft-copy ILO classification of radiographs and computer-assisted analysis methods.[10] Thus, for clinicians without access to analog technology no firm guidelines are available. In such cases, it seems prudent to have digital images interpreted by certified B readers using ILO guidelines, while taking note that digital technology may affect interpretation.

Diagnostic Imaging Techniques and Test Characteristics

Although surveillance continues to rely primarily upon CR due to feasibility considerations among others, conventional CT and HRCT play a pivotal role in the diagnosis of pneumoconiosis. In general, HRCT has demonstrated greater sensitivity and specificity with reduced inter-reader variability compared with that of CR for the evaluation of both asbestos and silica exposure.[7,11] Compared with conventional CT, HRCT similarly has been found to be more sensitive and specific in patients with clinical asbestosis. It has proven particularly useful in cases of equivocal parenchymal or pleural disease, unexplained pulmonary function test (PFT) abnormalities, obscuration of parenchyma by pleural disease or areas of fibrosis on CR, and concurrent emphysematous changes that must be distinguished from interstitial pathology.[11]

Case Conclusion

The sandblaster returned for follow-up surveillance 1 year later. Spirometry was slightly improved from the previous year: FEV_1 2.5 L (80% predicted), FVC 3.4 L (88% predicted), and FEV_1/FVC of 74%. A digital CR showed no pleural or parenchymal changes. Consistent with that interpretation, an inde-

TABLE 1
Chest Radiography Guidelines for Pneumoconiosis Surveillance

	OSHA: Silica*	OSHA: Asbestos	WHO: Asbestos	WHO: Silica	ACOEM: Silica†
Type of Film‡	Posterior-anterior	Posterior-anterior	Posterior-anterior	Posterior-anterior	Posterior-anterior
Interpretation	According to ILO/ICRP by a certified class B reader	According to professionally accepted classification; ILO/ICRP guidelines to be provided to readers who may be B readers, certified radiologists, or physicians with expertise in pneumoconiosis	According to ILO/ICRP	According to ILO/ICRP	According ILO/ICRP by physician with expertise in radiographic features of occupational lung disease
Frequency	Preplacement with B reading; then every 5 yr if under 20 yr exposure; every 2 yr if over 20 yr of exposure; and at employment termination. Frequency may be increased as determined by the examining physician	Preplacement CR; then every 5 yr if under 10 yr since first exposure; if over 10 yr since first exposure, every 5 yr up to age 35, then every 2 yr up to age 45, then annually for age >45; within 30 calendar days before or after date of termination of employment for exposures ≥TWA§ and excursion limit if determined necessary by physician	Preplacement CR; then every 3–5 yr if under 10 yr since first exposure; every 1–2 yr if over 10 yr since first exposure; and annually if over 20 yr since first exposure (frequency may be adjusted according to age of worker and intensity and duration of dust exposure)	Preplacement CR; then after 2 or 3 yr of exposure, then every 2–5 yr	Preplacement CR; if under 10 yr exposure, evaluation every 3 yr; if over 10 yr exposure, every 2 yr with complete evaluation at employment termination if last evaluation >1 yr prior; increased or reduced frequency based on questionnaire responses and documented exposure data; complete evaluation at termination of employment

*OSHA Special Emphasis Program; recommended if chronic exposure or more severe acute exposures to crystalline silica.
†ACOEM recommended if crystalline silica exposure concentration unknown or >0.05 mg/m^3; ie, the NIOSH Recommended Exposure Limit (REL) or essentially one half of the current OSHA PEL for pure crystalline silica.
‡presumably analog if ILO/ICRP used, though no explicit comments on digital radiography.
§TWA 0.003 mg/m^3 (0.1 fiber/cm^3).

pendent B reading of the digital image identified no pleural or parenchymal changes.

As illustrated by this case and emphasized by various expert guidelines, the diagnosis of pneumoconiosis requires the full integration of all data from the exposure history, the physical examination, PFTs, and different imaging modalities, rather than the B reading alone. The initial CR of this worker was most likely a false positive. Evidence for the greater specificity of HRCT compared with CR supports this interpretation, which was subsequently corroborated by negative plain films 1 year later. Given his respiratory history and occupational exposures, our sandblaster should continue to receive follow-up according to OSHA guidelines. Finally, until digital techniques have been validated for pneumoconiosis diagnosis and surveillance, some doubts will remain regarding the rigorous application of the ILO criteria when analog films are not available.

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