Biopersistence of Respirable Synthetic Fibers and Minerals: Point of View of the Chest Physician

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Problems of diagnosis related to the presence or absence of particles in lung and pleural tissues are discussed from the clinician’s viewpoint. The advantage of applying mineralogical analytical techniques is considered.

Key words: pathogenesis, diagnosis, mesothelioma, pulmonary fibrosis, bronchial carcinoma, biopersistence, asbestos, synthetic fibers

Introduction

From the chest physician’s point of view, problems related to the biopersistence of respirable particles are linked to the three classical aspects of diseases: pathogenesis, diagnosis, and prognosis.

Pathogenesis of Dust-induced Diseases

Exposure to minerals, particularly fibers, is associated with three main severe diseases: pulmonary fibrosis, bronchial carcinoma, and malignant mesothelioma. It is easily conceivable that prolonged retention of some types of minerals in the lung would be a stimulating factor for inflammatory and neoplastic processes, leading in turn to parenchymal fibrosis and peripheral cancer. The relationship between biopersistence in the deep lung and lesions of the large bronchi or the parietal pleura is much less evident.

Biopersistence and Pulmonary Fibrosis

Epidemiological and clinical data indicate that those fibers that resist pulmonary clearance mechanisms, such as crocidolite, amosite, tremolite, and erionite, are both strongly fibrogenic and carcinogenic. Nevertheless, there is evidence from clinical practice that exposure to certain types of nonpersistent particles may also lead to severe chronic diseases, including lung fibrosis. This is illustrated by the case report of a diamond polisher who had been exposed to cobalt dust arising from diamond–cobalt polishing discs, and died from severe lung fibrosis 8 years after the end of exposure. Analyses of his lung tissue showed only traces of cobalt, as is usually the case in cobalt- or hard metal-induced diseases. A hypersensitivity factor certainly plays a role in the pathogenesis of such diseases, and the solubility of cobalt appears to be an essential factor (1). It is evident that metallic cobalt is very different from fibrous silica or asbestos. Nevertheless, for a clinician, this illustrates that even nondurable particles may initiate inflammatory reactions that lead to parenchymal fibrosis.

Biopersistence and Bronchial Carcinoma

Are the factors of particle respirability and durability in the lung also relevant for the development of cancer of proximal airways, which are so easily reached by aerocontaminants? The very large majority of bronchial cancers that chest physicians encounter are, evidently, due to tobacco smoking, indicating that repeated and prolonged exposure to what are certainly nondurable substances may also lead to neoplastic transformation of the bronchial mucosa. The risk for an ex-smoker to develop a cancer takes more than 10 years to decrease to the level of a nonsmoker, indicating that definitive effects were induced before the carcinogenic agents disappeared.

Epidemiological studies show that the risk of bronchial carcinoma is increased in workers exposed to amphiboles, as well as to chrysotile, particularly in the textile industry (2), whereas glass fibers and fibers of rockwool and slagwool, with low durability and respirability are not associated either with lung fibrosis or mesothelioma (3). It may, however, not be possible completely to rule out their role in the elevated standard mortality ratio (SMR) observed for bronchial carcinoma in workers exposed to these latter fibers in the early industrial phase, when combined exposure to asbestos was current during that period (4).

Biopersistence and Mesothelioma

Experimental studies, in which animals received intrapleural injections of fibers, indicate that fibers most carcinogenic for the pleura are thin (<0.25 μ diameter) and long (>8 μ) (5). Clinically, malignant mesothelioma develops generally from the parietal pleura, but little is known about the mechanisms of translocation of asbestos fibers towards the pleura, nor whether they actually reach it.

In the few studies of pleural fiber burden, mainly small fibers of chrysotile were found in the parietal pleura. There was, however, no apparent relationship between the concentration and type of asbestos fibers in the parietal pleura and those in the lung parenchyma (6,7), perhaps due to complications resulting from sampling problems. It is probable that exogenous particles and fibers concentrate in some areas of the parietal pleura, similar to the anthracotic zones observed during thoracoscopy.

Biopersistence of Synthetic Fibers

Epidemiological studies of large cohorts of workers exposed to insulation wools have not shown an increased risk of either pneumoconiosis or mesothelioma (3). The fibers from rock- and slagwool generally have too large diameters to be respirable, and do not accumulate in the lung. Were synthetic fibers to be made that were both...
respirable and biopersistent, they might well represent a health hazard for the exposed workers.

Diagnosis

Histological Diagnosis

The diagnosis of pneumoconiosis requires the presence of particles in histological sections; that of silicosis, the association of fibrous nodules and silica; and of asbestos, peribronchiolar and interstitial fibrosis with asbestos bodies. The latter diagnosis depends on the presence of fibrosis and persistent mineral structures, and these criteria are still considered necessary for the diagnosis of asbestosis (8). Therefore, even in asbestos-exposed workers, if histology shows fibrosis in the absence of asbestos bodies, the preliminary diagnosis would not be asbestosis, and this could be a recurrent diagnostic problem in the future years because of the decreasing use of asbestos (especially amphiboles) and the low levels of dust exposure.

Clinical Diagnosis of Diseases (Mineralogical Analyses)

Chest physicians are rarely well informed about occupational exposure risks, and are unlikely, therefore, to establish a complete occupational history of their patients. Moreover, the patient himself may often be unaware of the risk to which he has been exposed, especially when the disease occurs several decades after the industrial exposure. These difficulties may be overcome by analysis of bioindicators, which can be of diagnostic interest in evaluating dust or fiber retention. Counting of asbestos bodies in bronchial alveolar lavage (BAL) or in digested lung tissue can be performed routinely (9), and electron microscopic qualitative and quantitative analyses of fibrous and nonfibrous particles in lung tissue and lavage are available for more specific, medicolegal or scientific purposes.

Cause-Effect Relationship. The presence of durable particles in a biological sample is not in itself a proof that the particles caused the disease; many factors must be taken into account, including duration and intensity of exposure, latency delays, and coexistence of other etiological agents. Nevertheless, a cause–effect relationship will appear more probable to the clinician when high concentrations of some types of minerals are found in biological samples, as is illustrated by two clinical observations. The first patient had been working with crocidolite for a few months during World War II. Forty-seven years later, he presented with pleural plaques and a left pleural effusion. Surgical exploration showed benign effusion with pleural thickening, and the lung biopsy revealed the presence of more than 7 million fibers of crocidolite/g of dry lung tissue. The persistence of a high burden of this type of fiber, together with pleural plaques, supported a diagnosis of benign asbestos effusion.

The second patient, a Turkish migrant from central Anatolia, presented with lung fibrosis with pleural thickening and calcification. He had never been occupationally exposed to asbestos, yet BAL yielded more than 1500 asbestos bodies/milliliter, all tremolite. A clinical diagnosis was made of environmental asbestosis that had arisen in his country of origin since tremolite was not used in the host country (10).

Influence of Biopersistence. These techniques are evidently applicable where there has been exposure to biopersistent material. Historically, in industry, workers were exposed to mixtures of amphiboles and chrysotile. As the chrysotile fibers are not biopersistent, the residual amphiboles serve as a marker of total exposure. Nowadays, chrysotile is virtually the only type of asbestos used so that mineralogical analyses may be of diminishing interest for diagnosis (11). When we performed BAL analyses on a group of workers in a brake lining factory who were exposed only to chrysotile (12), the concentrations of chrysotile asbestos bodies found during or soon after exposure were comparable to the concentrations of amphibole asbestos bodies found in asbestos-cement workers. However, when BAL was performed in one of the patients three years after exposure, a very significant decrease in concentration of asbestos bodies was recorded, corresponding to what is known about clearance of chrysotile. A converse illustration of the influence of biopersistence on diagnosis was the finding of amphibole asbestos in lung tissue from autopsies of workers exposed to man-made mineral fibers (13).

Influence of Sampling Site. Malignant mesothelioma can be associated with lung asbestos fiber concentrations no higher than would be found in unexposed subjects. Considering the problem of translocation, it is difficult to see the significance of such a low fiber burden in the lung and at a considerable distance from the target organ at the time of cancer progression, perhaps more than 30 years after exposure. Generally, when mesothelioma is diagnosed, the pleural cavity is full of tumoral tissue, making it impossible to take a sample of pleura that would yield an analysis of the mineral content representative of the fiber burden before malignant transformation. A sample taken from the contralateral side when autopsy is performed might give a more meaningful result.

Prognosis

A chest physician who is aware of the health risks consequent on exposure to mineral particles, will probably keep closer watch over patients who have been so exposed, and even if there is no specific treatment, he may still be able to restrict exposure to carcinogenic factors, such as smoking.

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