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Review

Elemental analysis of occupational and environmental lung diseases by electron probe microanalyzer with wavelength dispersive spectrometer

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ABSTRACT

Occupational and environmental lung diseases are a group of pulmonary disorders caused by inhalation of harmful particles, mists, vapors or gases. Mineralogical analysis is not generally required in the diagnosis of most cases of these diseases. Apart from minerals that are encountered rarely or only in specific occupations, small quantities of mineral dusts are present in the healthy lung. As such when mineralogical analysis is required, quantitative or semi-quantitative methods must be employed. An electron probe microanalyzer with wavelength dispersive spectrometer (EPMA–WDS) enables analysis of human lung tissue for deposits of elements by both qualitative and semi-quantitative methods. Since 1993, we have analyzed 162 cases of suspected occupational and environmental lung diseases using an EPMA–WDS. Our institute has been accepting online requests for elemental analysis of lung tissue samples by EPMA–WDS since January 2011. Hard metal lung disease is an occupational interstitial lung disease that primarily affects workers exposed to the dust of tungsten carbide. The characteristic pathological findings of the disease are giant cell interstitial pneumonia (GIP) with centrilobular fibrosis, surrounded by mild alveolitis with giant cells within the alveolar space. EPMA–WDS analysis of biopsied lung tissue from patients with GIP has demonstrated that tungsten and/or cobalt is distributed in the giant cells and centrilobular fibrosing lesion in GIP. Pneumoconiosis, caused by amorphous silica, and acute interstitial pneumonia, associated with the giant tsunami, were also elementally analyzed by EPMA–WDS. The results suggest that commonly found elements, such as silicon, aluminum, and iron, may cause occupational and environmental lung diseases.

Abbreviations: EPMA, electron probe microanalyzer; WDS, wavelength dispersive spectrometer; TBBs, transbronchial biopsies; EDS, energy dispersive spectrometers; HE, hematoxylin and eosin; GIP, giant cell interstitial pneumonia; HRCT, high-resolution CT; BALF, bronchoalveolar lavage fluid; UIP, usual interstitial pneumonia

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Contents

1. Introduction

Occupational and environmental lung diseases are a group of pulmonary disorders caused by inhalation of harmful particles, mists, vapors or gases. Occupational lung diseases, caused by exposure to harmful substances in the work place, are classified into two categories: diseases that are not occupation-specific, such as occupational asthma, and diseases related to a specific occupation, such as asbestosis, coal worker's pneumoconiosis, berylliosis, and farmer's lung. Lung diseases related to specific occupations usually develop slowly, are associated with exposure to toxic dust (such as asbestos and silica) over a period of 10–20 years, and can lead to interstitial lung disease and severe lung fibrosis. Pneumoconiosis, a type of interstitial lung disease, is caused by inhaling inorganic dusts, particularly coal dust [1]. Diagnosis of pneumoconiosis is relatively simple and is based on chest radiographs, pulmonary function tests, and the occupational history of the patient. Mineralogical analysis is not generally required in the diagnosis of most cases of occupational and environmental lung diseases. However, when mineralogical analysis is required, quantitative and semi-quantitative methods must be employed, as the lungs of even healthy individuals contain small quantities of mineral dust deposits, with the exception of those minerals and elements that are rarely or only encountered in specific occupations. For example, tungsten and cobalt are only observed within the lungs of subjects who have been exposed to hard metals [2,3]. Since the techniques of mineralogical analysis are time-consuming and expensive, they have been mostly used as research procedures only.

An electron probe microanalyzer (EPMA) is an analytical tool used to non-destructively determine the chemical composition of small volumes of solid materials. It works in a similar manner to a scanning electron microscope. When the sample is bombarded with an electron beam, x-rays generated from elements within the sample are detected by an electron microprobe. The wavelengths of the emitted x-rays are characteristic to the elements that are being analyzed. EPMA with a wavelength dispersive spectrometer (EPMA–WDS) has been extensively used in the field of material sciences. We have utilized EPMA–WDS to analyze human lung tissue in both qualitative and semi-quantitative ways to create element distribution maps [4]. In this review, we discuss the clinical application of EPMA–WDS as a promising technique for mineralogical analysis of lung samples from patients with occupational and environmental lung diseases.

2. Analytical methods for mineral particle analysis of lung tissue

2.1. *Pathologic examination*

Histologic examination is the basic pathologic tool for classifying occupational and environmental lung diseases. Dust resides in the lungs of all individuals, particularly smokers and those living in polluted environments. It is typically observed around the small airways, blood vessels, and in the subpleural and interlobular connective tissue. However, in individuals with occupational and environmental dust exposure, fairly large numbers of particles are observed in these locations, as well as in the alveolar spaces, and the alveolar interstitium. Mineralogical analysis is not generally required in the diagnosis of most cases of occupational and environmental lung diseases, as simple light microscopic observation and polarization is sufficient.

A surgical lung biopsy is a procedure to remove samples of lung tissue for examination under a microscope and mineralogical analysis. Although transbronchial biopsies (TBBs) may also be used for pathologic examination and elemental analysis, they have limited value to the pathologists particularly when dealing with suspected cases of occupational and environmental lung diseases. TBBs usually contain the peribronchial connective tissues, which are a common repository