AN X-RAY MICROANALYTICAL STUDY OF A CASE OF PULMONARY BARIUM GRANULOMA

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A case of pulmonary barium granuloma due to old-time aspiration of barium sulphate during contrast X-ray examination was studied using an electron probe X-ray microanalyser with a computer system. The results revealed the presence of abundant barium sulphate in situ.

Barium granuloma of the lung is a complication very rarely encountered after contrast X-ray examination of the digestive tract. Although gastrointestinal barium granuloma has been described rather frequently (1, 2, 8, 9, 10-12, 14, 21), only a few cases (6, 7, 12, 15) have been reported, without X-ray microanalysis, of barium granulomas occurring in the lungs as a result of accidental aspiration of barium sulphate. Barium granulomas occurring in the gastrointestinal tract (10, 13), esophagus (11) and other tissues (4, 5) have been investigated by means of an energy dispersive X-ray analyser. To our knowledge, this report seems to be the first to describe computer-assisted X-ray microanalysis of barium sulphate deposition in human pulmonary granulomas.

MATERIALS AND METHODS

The patient, a 78-year-old male, died of dyspnea and cardiac insufficiency. A contrast X-ray examination of the gastrointestinal tract had been performed 20 to 30 years ago.

Autopsy established pathological diagnoses consisting mainly of pericarditis tuberculosa, barium granuloma of the right lung, bronchopneumonia and tuberculosis of the lungs.

Following macroscopical observation, histological examination was carried out on the lung tissue fixed in 10% formalin. The deparaffinized sections were stained with hematoxylin and eosin. Some of the sections were stained by the Waterhouse's sodium rhodizonate method (4, 20) and examined under polarized light to identify barium deposits in the "barium granuloma".

X-ray Microanalysis of the Lung

For electron microscopic examination, a small portion of the formalin-fixed
block was immersed in phosphate buffer (pH 7.2), postfixed with 1% OsO₄ in the same buffer and, after dehydration in alcohol, embedded in epoxy resin.

The ultrathin sections, 80–100 nm thick, were mounted on carbon-film coated grids, coated with carbon and then examined using a transmission electron microscope (JEM-100C) equipped with a scanning device (ASID-4) as well as an energy dispersive X-ray microanalyser unit (EDAX-707B) coupled with an EDIT-computer system. This system permitted both elemental spot analysis and pulse analysis of the distribution of X-ray lines in the specimens. Using a Hitachi H-500 electron microscope, the logged area of the specimens were also examined after treatment for electron scanning. A sample prepared with fresh Barex molt S (radiographic contrast medium) was used as a contrast in the analysis. A small amount of Barex molt S was analysed on a carbon-film coated grid under the same analysing conditions as used for the sections from the pulmonary barium granuloma.

RESULTS

Pathoanatomical Findings of the Right Lung

Light microscopically, the lesion proved to be granulomatous tissue predominated by clusters of large macrophages that were filled with a fine, granular, slightly yellowish-white material, mostly devoid of inflammatory infiltrates (Fig. 1). Occasionally some multinucleated giant cells filled with the same material were found. No fibrosis was recognized.

The fine granules displayed whitish birefringence under polarized light (Fig. 2). Waterhouse’s sodium rhodizonate staining (20) disclosed a granular material of deep reddish-brown color.

Fig. 1. A light microscopic view of the lesions of the right lung (see text). ×134
Fig. 2. The granular material in the granulomatous tissue displays whitish birefringence under polarized light. ×67

Fig. 3. An electron micrograph showing a part of the macrophage cytoplasm containing numerous granules in the granuloma. Note accumulation of clusters of irregularly shaped granules of high electron density within the cytoplasm of the macrophage. N: nucleus of the macrophage, Co: collagen fiber. It seems that most of the cell organelles were destroyed during long fixation in 10% formalin. ×3,000
Electron Microscopic Findings

As shown in Fig. 3, clusters of irregularly shaped granules of high electron density were found in the cytoplasm of a macrophage in the barium granuloma of the lung.

X-ray Microanalysis of the Lung

Figure 5 shows the line profile obtained in a scanning transmission electron micrographic (STEM) image (Fig. 4) by pulses of X-ray lines, Ba(Lα) and S(Kα). This profile indicates two distinct X-ray dispersion patterns of barium and sulfur.
X-ray Microanalysis of Pulmonary Barium Granuloma

The X-ray point analysis of those granules revealed two conspicuous peaks corresponding to the X-ray pulse lines Ba(La) and S(Kα). The average X-ray energy intensity of sulfur in the pulmonary barium granuloma was highest. On the basis of this intensity as 1.0000, other average elemental intensities were obtained. The ratio of the Ba(La) line to the S(Kα) line was estimated to be approximately 0.8. The X-ray point analysis of the control sample revealed two conspicuous peaks corresponding to the X-ray pulse lines Ba(La) and S(Kα) respectively and the average X-ray energy intensity of the control sample BaSO₄ revealed the lines S(Kα), Ba(La) and Ba(Lβ₁) representing intensities identical to those in the pulmonary barium granuloma. These data strongly suggested that the granular substance within the cytoplasm of the pulmonary macrophages was BaSO₄.

Combined X-ray spectra (Fig. 6) were obtained after treatment with “strip elements” and background subtraction by “subtract memory” (16). Namely, the dotted lines S(Kα) and Ba(La), comparable to the point analysis obtained from the pulmonary granuloma, were superimposed on S(Kα) and Ba(La), appearing corresponding to the elliptical-shaped, electron-dense material observed in STEM.

Fig. 6. Comparison of the X-ray energy spectra between pulmonary “barium granuloma” and control sample of BaSO₄.

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\text{: Pulmonary "barium granuloma"}
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\text{: Control sample: BaSO₄.}
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as clusters of white vertical lines and comparable to the point analysis of the control sample of BaSO₄. The results demonstrated a close match of both energy spectra with each other. The X-ray energy ratios of the elemental lines S(Ka), Ba(La) and Ba(Lβ₁) in the pulmonary barium granuloma of this case and in the control samples of barium proved to be almost the same.

DISCUSSION

According to Russ (16) and Mizuhira (16–18), for quantitative expression of the results, the total count for each element can be used either with appropriate standards or with already established calibration curves to obtain the respective absolute elemental masses or concentrations, and the elemental concentration ratios can be calculated without standards.

In this paper, the highest X-ray energy intensity ratios in the barium granuloma and standard controls were compared by use of a “manual thin section quantitative calculation” program (16–18). The results of quantitative analyses using the computer system indicated a close similarity between the X-ray energy ratios of the elemental lines S(Ka), Ba(La) and Ba(Lβ₁).

This finding suggests that barium sulphate aspirated by the patient into the lung 20 to 30 years ago remained in situ without undergoing significant chemical changes.

Moreover, the light microscopical and X-ray microanalytical results obtained in the present case showed that phagocytized barium sulphate appears in the barium granuloma as an intracellular, finely granular, yellowish-white material revealing whitish birefringence under polarized light. Although the birefringence of pure barium sulphate is seen in vitro (13), in histological sections barium sulphate appears as a finely granular, non-birefringent material, and as larger, needle-shaped or rhombic birefringent crystals (10, 13, 21).

Accordingly, the findings obtained in this study seemed to be related to the history of fortuitous aspiration of barium sulphate into the lungs 20 to 30 years ago, because a change in the physiological properties of barium sulphate such as birefringence has been suggested to be the result of long-term complete phagocytosis (13).

REFERENCES