A Study of Magnetic Field in the Lung of Workers in an Asbestos Factory

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Abstract: Magnetic field at the chest in 93 male workers exposed to asbestos dust in an asbestos products factory in China was studied by local magnetization and flux-gate gradiometry. The average field intensity at 12 measurement points over the anterior chest wall was compared among workers with and without asbestosis and among workers of different working age. The field intensity in workers with asbestosis and those suspected to have asbestosis on the basis of X-ray findings was significantly higher than that in workers without asbestosis. It was also found that the field intensity increased with working age. It is suggested that dynamic measurement of magnetic field in the lung of workers exposed to dust containing ferrimagnetic particles would at least serve as a quantitative method for estimating lung dust loads and be valuable for pneumoconiosis prevention.

Key words: Local magnetization — Flux-gate gradiometry — Remnant magnetic field — Magnetopneumography — Demagnetizer — Asbestosis

INTRODUCTION

The dust inhaled and retained in the lungs of workers may contain ferrimagnetic particles, such as magnetite (Fe_3O_4), etc. When the thorax is magnetized by a magnetic field of medium intensity (about 10^2 Oersted) for a short time (e.g., several seconds), the remnant magnetic field produced by these particles can be detected by a magnetometer. This represents the magnetic field of the lungs. A magnetopneumograph shows the distribution of this field measured at different points over the chest, and provides a non-invasive physical method that may be used to study the amounts of magnetic dust and the proportion of dust accumulated in the lungs.

Magnetopneumography was first reported by D. Cohen.¹⁾ For individuals in the general population, the field intensity of the lungs is rather weak, ranging

from about 10^{-2} nT (nanotesla) downward,²⁾ and can only be detected by a SQUID (superconducting quantum interference device) gradiometer³⁾ with spatial discriminability. However, for some kinds of workers occupationally exposed to dust containing relatively higher amounts of magnetic particles, such as welding workers, foundry workers and manufacturers of asbestos products, lung fields are about 10^{-1} – 10^1 nT^{4–8)} and can be measured by a flux-gate gradiometer under low magnetic noise conditions. This less sensitive but simpler instrument is also desirable because of its lower cost and maintenance. This approach can therefore be used as a new way of monitoring the amounts of dust accumulated in the lungs of workers due to occupational exposure, and for the diagnosis of pneumoconiosis. In this study, we measured the lung field in 93 workers in an asbestos products factory in order to explore the application of magnetopneumography to industrial hygiene.

METHODS

The subjects were workers at an asbestos products factory, either actively or passively exposed to dust, and with or without asbestosis. Their types of work included raw asbestos processing, asbestos softening, asbestos combing, asbestos spinning, asbestos weaving, asbestos rubber production, machine repair and product transport. The raw material used in this factory contained relatively small amounts of magnetic particles. The localized field produced by a coil with a 6×6 cm² iron core was used to magnetize separate areas of the lung. This field, normal

Fig. 1. Location of 12 measurement points.

to the frontal plane of the chest, was applied for 10 s, being attenuated from 230 mT (millitesla) at the skin to 30 mT at a thoracic depth of 10 cm.

Twelve measurement points were set on the anterior side of the thorax, as shown in Fig. 1. Lines 15 and 26 equally divided the distance between the outer edge of the sternum and the anterior line of the axilla. Points 1 to 6 for the right lung were the intersection points of these lines and the 1st, 3rd and 5th intercosts. The same applied to points 7–12.

Each subject was stripped to the waist and free from any magnetic articles. The lung region below four neighboring points, such as 1, 2, 4 and 3, was placed in contact with the iron core of a localized field magnetizer and then magnetized by a direct current field. Then, the remnant fields in the lung at these four points were measured one by one with a flux-gate gradiometer. The field intensity normal to the skin at any point was taken by subtracting the reading when this point was near to the probe of the gradiometer (2 mm distant) and when the subject moved away from the probe later (about 20 cm distant). After the lung fields at these four points had been measured, this lung region was demagnetized by the same magnetizer, but now used as demagnetizer carrying an attenuating alternating current. Then, another region of four points 3, 4, 6 and 5 was magnetized, measured and demagnetized. The same procedures were conducted for the left lung.

RESULTS AND DISCUSSION

The average remnant magnetic fields for different groups classified according to the grade of asbestosis (using Chinese diagnostic criteria*) and activity of the 93 subjects in the asbestos products factory are given in Table 1. Also, the average fields for two lungs in three groups of active workers relative to the degree of asbestosis diagnosed by roentgenogram are shown in Fig. 2.

After processing the field data for two lungs in Table 1, we obtained results for the five groups with different grades of asbestosis and work activity:

1. The differences among the field data for these groups were statistically significant ($F=31.52$, $p<0.01$).

2. The levels of field for active worker groups—group D with suspected asbestosis, group C with asbestosis grade I and group E with normal roentgenograms—were significantly higher than those for passive groups—group A with asbestosis II and group B with asbestosis I ($p<0.01$).

3. Among the active groups, the field levels for groups C and D were statistically higher than that of group E ($p<0.01$), but the difference in field between groups C and D was not statistically significant ($p>0.05$). Thus, the field values of workers were closely related to their degree of activity. The relatively lower

* This is fundamentally the same as the ILO classification. A detailed comparison of them was published in *Ann. Occup. Hyg.*, 1984; 28: 1–13.

Table 1. Measured results of lung fields

Group	Number	Activity	Average years of exposure	Average remnant magnetic field (nT)		
				Right mean $\pm$ SE	Left mean $\pm$ SE	Two lungs mean $\pm$ SE
A. Asbestosis grade II	13	Retired for more than 5 years	24.8	.207 $\pm$.026	.188 $\pm$.024	.197 $\pm$.018
B. Asbestosis grade I	12	Changed to be passive	26.8	.163 $\pm$.015	.108 $\pm$.013	.135 $\pm$.010
C. Asbestosis grade I	12	Active	31.3	.538 $\pm$.075	.433 $\pm$.065	.486 $\pm$.050
D. Suspected asbestosis	28	Active	22.4	.524 $\pm$.034	.414 $\pm$.029	.469 $\pm$.023
E. Normal roentgenogram	28	Active	15.3	.436 $\pm$.030	.352 $\pm$.025	.394 $\pm$.020

Fig. 2. Average fields of two lungs for groups of active workers versus those with asbestosis.

field values of subjects with asbestosis who ceased to work at dust sites for a certain period (groups A and B) seem to indicate that free dust inhaled into the lungs was continually removed through the respiratory tract, despite the fact that pathological changes were still advancing. From the higher field value in group D with suspected asbestosis compared to that in group E with normal roentgenograms, it seems worthwhile to further study the value of magnetopneumography for the early diagnosis of asbestosis.

The average fields at each measurement point for these five groups are shown in Fig. 3. It is evident that the field value at each point in the right lung for any

Fig. 3. Average fields at each point for different groups:

- A—Asbestosis grade II (Retired)
- B—Asbestosis grade I (Passive)
- C—Asbestosis grade I (Active)
- D—Suspected asbestosis (Active)
- E—Normal roentgenogram (Active)

Table 2. Average fields for Groups with different nos. of working years

Group	Working years	Number	Active		Passive	
			Number	Field (nT)	Number	Field (nT)
1	0—10	16	14	0.435	2	0.058
2	11—20	22	18	0.450	4	0.115
3	21—30	29	20	0.384	9	0.246
4	>31	26	16	0.509	10	0.140
			F=3.03		F=13.4	
			p<0.05		p<0.01	

group was greater than that at the corresponding point in the left lung with only a few exceptions; also, the field value at measurement point 4 or 9 (see Fig. 1) was the highest among all points in the right or left lung, respectively. The latter finding indicates that the concentration of magnetic dust in the hilar region is the most dense. As to the higher field value at upper measurement points (e.g., points 1 and 2) in the lung relative to that at corresponding lower points (points 5 and 6), this could be due to the larger measurement distance between the probe and the lung for the lower point.

The average fields for different groups classified according to the number of working years at the dust site and degree of activity of the 93 subjects are given in Table 2. Here, the average fields of the four groups for both active and passive showed a tendency to increase with the number of working years and the field differences for either of the four groups were statistically significant. However, for active cases, group 3 had a lower field than the other three groups, and for passive cases, the field in the group 4 was lower than that in group 3, but higher than those in groups 1 and 2. This might be due to the complex factors affecting the quantity of dust accumulated in the lungs, such as the concentration of dust at the work sites, personal dust-protective measures and personal ability for respiratory tract clearance, in addition to the number of exposure years.

The above results confirm that magnetopneumography is an effective method for detecting dust accumulated in the lungs of workers due to occupational exposure. It is suggested that the lung fields of workers exposed to dust should be periodically measured and a magnetopneumographic file created for each worker for these dynamic data. These data could be used as a quantitative warning signal of pneumoconiosis risk and as an evaluation index of dust control in a factory when the incidence of this disease is taken into consideration. This approach would be valuable for the prevention of the pneumoconiosis.

From the present data, the magnetic field in the lungs of asbestos workers is considered to be caused by the accumulation of asbestos dust in accordance with occupational history.

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