INVESTIGATIONS CONCERNING THE PRE-RADIOLOGICAL STAGE OF SILICOSIS

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Twenty-two gold-miners were studied in detail six-monthly for two years after first entering mining. Six men working in the dustiest part of the mine (8,000 to 45,000 particles/ml. all sizes, in rock containing 72% free and combined silica) showed a progressive increase of blood silica, a fall in erythrocytes, and a rise in eosinophils and monocytes. The changes observed were statistically significant only in those exposed to the highest concentrations of dust and occurred before abnormalities were detectable in the chest radiograph.

Several studies have been published since 1930 which demonstrate that silicotic patients exhibit more or less pronounced biochemical and metabolic changes, as well as lesions in many viscera. The systemic features of silicosis are considered to be a consequence of the development of pulmonary lesions, while the clinical picture is considered to be a local and systemic, direct and indirect reflection of the morphological changes occurring within the lungs (Schmid, 1956). Certain authors believe that the constitutional disturbances result from a transition from the compensated, pulmonary form to the decompensated, pleuro-visceral form (Moskovski, 1956).

The existence of an evolutionary stage of the disease preceding the onset of the radiological lesions lacks the support of special investigations in this field.

While some investigations have been carried out on the clinical symptoms and functional respiratory tests during the pre-radiological stage of silicosis, we have not come across any longitudinal study, performed over several years in the same group of persons, on alterations in the biochemistry. In our opinion, the need for such investigations seemed all the more important, as we noticed that certain authors consider some of these biochemical changes to be the first sign of the complex disturbances occurring in the course of silicosis. These include more particularly eosinophilia (Rovatti, 1948), increased erythrocyte sedimentation rate (Wiesinger, 1949), altered Na/K ratio (Beckmann and Hilgers, 1957), increased amount of lysozymes and lipoids (Schumacher, 1956), and an increased amount of α_2 -

globulins and γ globulins in the blood (Timar, 1955).

We have undertaken a follow-up study of the biochemistry and clinical pathology of persons starting work in an atmosphere polluted by various amounts of dust containing silica, as well as of the possible prognostic and prophylactic significance of these changes.

Material and Method

The mine in which our investigations were carried out is formed of rocks of volcanic origin. The seams are formed for the most part of auriferous quartz and of iron and lead sulphides. Free and combined silica in these seams is about 72%.

About 80% of the amount of dust released is due to blasting and the remaining 20% to mucking out. In certain areas the number of dust particles increases to maximum concentrations of 45,000/ml. (all sizes).

About 10% of the total weight of dust is in particles between 0 and 1μ in diameter, and 50-68% between 1 and 3μ . In these conditions, one case of silicosis has occurred in less than three years. Apart from this case, the first radiological changes in the pulmonary pattern were noticed after at least five to seven years of exposure to dust (Daniello, 1953). The incidence of the disease was about 10% of the total number of cases under investigation.

These findings enabled us to investigate, at intervals of six months over a period of two years, whether any changes appeared on clinical and laboratory examination before the first changes in the chest radiographs were detected.

The investigations were carried out on 33 subjects, 22 working underground and 11 at the surface in the offices of the plant.

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All 33 subjects were aged between 18 and 30 years. They all came from rural areas and had never been exposed to silica dust or toxic gases. None of the subjects had had miners among near relatives.

The 22 underground workers were divided into four groups:

Group A included six men who worked in the areas of maximum dust concentration (from 8,000 to 45,000 particles/ml.) during their whole underground working time. They were miners and miners' assistants.

Group B included persons who worked alternately in the areas of minimum, medium, and maximum dust concentration (from 150 to 30,000 particles/ml.). This group consisted of wagoners.

Group C included persons who worked most of their time underground in areas of minimum dust concentration (from 150 to 500 particles/ml.). This group consisted of technicians, plumbers, engineers, joiners, and sanitary officers.

Group M included persons who worked at the surface, in the offices of the plant, in an atmosphere which was not polluted by dust or gas.

The first clinical and laboratory examinations were carried out during the period preceding the training for underground work. Only those workers in whom all these examinations were normal were selected and followed up after they began working in the mine and inhaling dust containing silica.

The following investigations and determinations were made at six-monthly intervals for two years: physical examination, chest films and radioscopy, electrocardiogram, basal metabolism, blood count and haematocrit, erythrocyte sedimentation rate, blood silica (King's method), blood potassium (Hoffman and Jacobs' method), blood calcium (Clark-Collip's method), ascorbic acid in the blood (Roc and Knether's method), blood cholesterol (Sackett's method), proteinaemia (Hinsberg-Lang's method), silica in the sputum (King's method), and urine analysis.

Results

The correlation coefficient (*r*) between the increase of blood silica level and the duration of exposure is 0.88 and the regression of blood silica levels on

TABLE 1
BLOOD SILICA IN GROUP A

Months	0	6	12	18	24
Blood silica (mg./%)	0.24	0.38	0.62	0.82	0.91

Normal values 0.05-0.30 mg. %.

the duration of exposure is given by the equation $y = 0.17 \times - 0.06$.

Tables 1 and 2 show that in miners in group A (subjected to a maximum concentration of silica dust) there is a rise of blood silica and in the eosinophil and monocyte counts which is statistically significant. There is also a significant fall in the red cell count.

The differences recorded in the value of other biological indices are not statistically significant in this group nor were there any significant differences in the other groups exposed to less dust.

Discussion

The silica determinations in the blood enabled us to detect, in these rather small groups, what we think is the most interesting and important change that occurs during the pre-radiological stage in potentially silicotic subjects. In the miners who for two years inhaled particles in concentrations varying from 8,000 to 45,000/ml. containing 72% silica, blood silica rose to three or four times the amounts found before exposure. The silica in the blood remained nearly normal in all the other subjects who worked during the same two years in an atmosphere in which dust pollution was slight or absent.

Our observations tend to show that the rise is all the more significant if we consider changes in the individual because the initial level may be lower in some subjects. In maintaining that there is a direct connexion between the degree of dust concentration and the increase of blood silica, we are taking into account not only the results obtained in Group A,

TABLE 2
BLOOD COUNTS AND HAEMATOCRIT IN GROUP A

Months	Erythrocytes (per c.mm.)	Haemoglobin (%)	Colour Index	Leucocytes (per c.mm.)	Segmented Neutrophils (%)	Non-segmented Neutrophils (%)	Eosinophils (%)	Basophils (%)	Lymphocytes (%)	Monocytes (%)	Haematocrit
0	4,066,000	87	0.97	6,800	53	7	1.5	0	29	7.8	41
6	4,270,000	88	0.91	6,980	60	4	2	0	22	12	43
12	4,220,000	84	0.87	6,440	55	1	2	0	30	12	42.5
18	3,870,000	76	0.90	6,500	51	2	5	1	28	13	36
24	3,570,000	70	0.90	5,800	50	2	4.8	0	28	12.8	34
P	<0.01						<0.01			<0.01	

but also those obtained in the other groups. Employees who worked the same number of hours daily, over the same period of two years, with presumably the same variations of the alimentary intake of silica, but in areas in which dust was present in moderate or minimal concentrations, or even absent, do not exhibit this gradual increase in blood silica. The direct relationship existing between blood silica and the dust concentration is also supported by our observations in employees who changed their workplace during the six months' period which separated two examinations. Thus, at the end of one year's work in an area with maximum dustiness, H.A. exhibited an increase of blood silica from 0.15 mg.% before entering the mine to 0.45 mg.%. During the next year, he worked in an only slightly polluted area of the same mine and blood silica dropped to 0.10 mg. %.

Our results are in accord with other published observations (Desoille, Dérobert, Le Breton, Lafuma, and Vacher, 1955; Timar, 1955).

The blood counts in Group A showed an increase in erythrocytes during the first year of underground work, followed by a fall at the end of the second year. This tendency towards an increase in erythrocytes was found in all groups of workers who began underground work, regardless of the concentration of inhaled dust. As a rule, haemoglobin showed similar trends.

The increase in eosinophils and monocytes was almost constantly present in pre-silicotic and silicotic subjects. They can be considered as very early signs in determining prognosis and prophylaxis. In our conditions of investigation they become apparent in potentially silicotic subjects three to five years before the disease could be detected by means of radiological examination.

From our studies we think that the humoral phase of silicosis begins during the second year of exposure to dust, and precedes by three to seven years the radiological phase of the pulmonary localizations. Some of the workers displaying these humoral disorders will in all probability develop no nodular lesions even after inhaling dust for three to seven years and remain only potentially silicotic subjects for a long time. They will only show alterations in biochemistry, a form of clinically and radiologically inapparent silicosis.

We believe that the chief element of the pathogenetic mechanism in the generalization of silicosis is the toxic influence of increased blood silica. This might account for the frequent dissemination of the silica throughout the body with the occurrence of necrotic lesions and connective tissue proliferation in the vascular walls, aorta, myocardium, digestive tract, pancreas, bile ducts, liver, spleen, kidneys, and nervous system. These lesions have also been reproduced experimentally by the parenteral injection of silicic acid. The toxic action of silica upon the adrenals might partly explain the secretory failure reported by certain investigators, which is said to be reflected clinically in the frequent asthenia, adynamism, and anorexia.

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