Radiographic changes in a group of chrysotile miners and millers exposed to low asbestos dust concentrations

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ABSTRACT Radiographic changes in 342 Quebec asbestos miners exposed to low levels of asbestos dust for an average period of 20 years were studied. Their estimated cumulative exposure ranged from 7 fibres per cubic centimeter $\times$ years (f-y/cc) to 300 f-y/cc. Of these workers, 2.1% showed a small opacity score of 1/0 or more and 2.7% showed pleural changes. No linear relationship could be established between small opacity score and any index of exposure to asbestos. Pleural changes were related to age. A referent group of office workers within the same mining industry showed a prevalence of 2.1% (1/48) for small irregular opacities 1/0 or more, and for pleural changes.

Numerous studies on asbestos related diseases have improved our understanding of the pathogenesis of the various mineralogical types of asbestos and shown the influence of the different stages of processing of the fibre.¹ Qualitative associations between exposure to asbestos and type of disease have been established, and some quantitative relationships between indicators of exposure and biological response have been built up.² There is still, however, a need for studies which could help in evaluating the preventive potential of present hygiene standards¹⁻³—that is, studies of populations exposed to low concentrations of asbestos dust for a long time. An opportunity arose to study radiographic changes in a group of Quebec chrysotile miners, whose estimated cumulative exposure ranged from 7 fibres per cubic centimeter $\times$ years (f-y/cc) to 300 f-y/cc and whose exposure had started between 27 and 10 years ago. We report the results of the study.

Methods

POPULATION

The company under study has operated a mining complex in the region of Thetford Mines since 1958.

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From its inception dust control has been a priority and improvements in methods of control have been made regularly. All male workers (682) first employed at the company between the beginning of construction (1954) and the end of 1969 and who had accumulated at least five years of exposure were listed. All workers who had spent more than six months in another asbestos mine or factory or who had worked for more than one year in another non-asbestos mine were excluded. Of the 394 remaining workers, 82 had left the company in 1979 or before and 30 of them agreed to participate in the study, giving a total study group of 342 (table 1).

MEDICAL VARIABLES

In 1975 results of yearly medical examinations comprising full size posteroanterior chest radiographs, clinical examination, and lung function tests for all workers employed in an asbestos mine of the region were centralised at the Institut de Médecine Industrielle in Thetford Mines (IMIT). For the 312 men still in the mine, the most recent chest radiographs, up to and including 31 December 1980, were provided by IMIT. Twenty former workers had a chest radiograph examination by our group during the autumn of 1981, and the remaining radiographs came from regional hospitals where ten workers had already been examined during 1980. The 342 radiographs were read according to the ILO U/C 1980 classification by five readers (radiologists and pul-

Table 1 Description of the study population

No of workers first employed between 1954 and 1969, with five years of exposure	682
Excluded:	
Worked in other mines	282
History of thoracic surgery	6
Study population:	394
A medical record at IMIT in 1979 or 1980	312
Left company in 1979 or before:	
Deceased workers	19
Untraced workers	10
Traced workers	53
Traced workers:	
Rejected workers (other mines)	6
Refusal	9
No answer	2
Did not attend examination	6
Attended medical examination	30
Study sample	342

IMIT = Institut de Médecine Industrielle.

monary physicians) experienced in the reading of pneumoconioses. Two were from Quebec and three from Louisiana. All were B-readers certified by NIOSH. Each worked independently using his own set of standard radiographs. The films were provided in random order and the readers were totally ignorant of the individual's occupation or his exposure to asbestos.

EXPOSURE CHARACTERISATION

Exposure to asbestos was characterised by the following variables: year of first exposure, number of years exposure, cumulative index of asbestos exposure expressed in f-y/cc, and average exposure to asbestos in f/cc (computed as cumulative exposure ÷ number of years of exposure). These indicators were

drawn from the occupational history of the employee, from available dust measurements, and from estimations given by company hygienists. Since 1976, weekly dust measurements have been carried out in several locations, using a membrane filter. For most of the years between 1958 and 1976 one or several samples were taken using a midget impinger. On some occasions measurements were done by the two methods for ad hoc surveys. No past measurements were available for the pit (open) or the office, or for different tasks at the same location (bagging inside the mill, or drilling inside the pit, for instance). These limitations did not permit the definition of as many yearly measurement curves as would be needed to take into account all the different exposures. Therefore the cumulative index of exposure was computed according to a procedure described by Gibbs⁴ using estimates of yearly fibre concentrations at seven job locations: pit, crusher, dryer, mill, office, yard, skilled workers.

OTHER VARIABLES

Other variables such as date of birth, medical antecedents, and smoking habits were derived from the medical records kept at IMIT, and were updated for those workers who had left the mine.

RESULTS

Of the 342 radiographs, 331 were read by all five readers (11 films of poor quality were rejected). The prevalence of small irregular opacities 1/0 or more was 2.7%, 1.2%, 3.0%, 3.6%, and 24.0% for the five readers. Reader 5 was clearly outside the range

Table 2 Prevalence of small irregular opacities and pleural changes according to several variables

	No of workers	Small irregular opacities 1/0 or more	Pleural thickening			Pleural calcification	Any pleural changes (except CA)
			Diaphragm	Chest wall	Costophrenic angle (CA)		
Overall	331	7 (2.1%)	5 (1.5%)	8 (2.4%)	12 (3.6%)	2 (0.6%)	9 (2.7%)
Age:							
< 40	60	0 —	0 —	0 —	1 (1.7%)	0 —	0 —
40-49	149	4 (2.7%)	1 (0.7%)	3 (2.0%)	2 (1.3%)	0 —	4 (2.7%)
≥ 50	122	3 (2.5%)	4 (3.3%)	5 (4.1%)	9 (7.4%)	2 (1.6%)	5 (4.1%)
Smoking habits:							
Smoker	157	5 (3.2%)	3 (1.9%)	3 (1.9%)	5 (3.2%)	1 (0.6%)	4 (2.5%)
Ex-smoker	118	1 (0.8%)	1 (0.8%)	3 (2.5%)	5 (4.2%)	1 (0.8%)	3 (2.5%)
Non-smoker	55	1 (1.8%)	1 (1.8%)	2 (3.6%)	2 (3.6%)	0 —	2 (3.6%)
Unknown	1	—	—	—	—	—	—
Time since first exposure:							
< 20 years	85	1 (1.2%)	0 —	0 —	1 (1.2%)	0 —	0 —
≥ 20 years	246	6 (2.4%)	5 (2.0%)	8 (3.3%)	11 (4.5%)	2 (0.8%)	9 (3.7%)
No of years of exposure:							
< 10	18	1 (5.6%)	1 (5.6%)	1 (5.6%)	1 (5.6%)	0 —	1 (5.6%)
10-19	91	1 (1.1%)	0 —	1 (1.1%)	1 (1.1%)	0 —	1 (1.1%)
≥ 20	222	5 (2.3%)	4 (1.8%)	6 (2.7%)	10 (4.5%)	2 (0.9%)	7 (3.2%)
Cumulative index of exposure: (f/cc × years):							
< 30	42	0 —	1 (2.4%)	1 (2.4%)	2 (4.8%)	0 —	1 (2.4%)
30-89	155	5 (3.2%)	3 (1.9%)	5 (3.2%)	7 (4.5%)	2 (1.3%)	5 (3.2%)
≥ 90	134	2 (1.5%)	1 (0.7%)	2 (1.5%)	3 (2.2%)	0 —	3 (2.2%)

defined by the four other readers and therefore his results were analysed separately.

From the four readings, a summary score for small opacities was computed according to the procedure described by Oldham.⁵ Pleural changes were considered to be present if they were recorded by at least two of the four readers. Table 2 shows the variations in the prevalence of small irregular opacities (1/0 or more) and pleural changes according to several variables. Age, smoking habits, and time since first exposure are the only variables that seem to show an association with the prevalence of radiographic changes, although no statistical significance is reached. No association is seen with duration of exposure or with cumulative index of exposure. We performed two separate multivariate analyses of small opacity score and presence of pleural change using the following independent variables: age, smoking habits, and exposure to asbestos. The only

significant association was found between pleural change and age ($p < 0.03$).

In table 3 the characteristics of the seven workers whose chest radiograph showed small irregular opacities of grade 1/0 or more are shown. Five smoked one pack of cigarettes a day. One mentioned having cough and phlegm for two consecutive years which suggested that he may have chronic bronchitis, although his lung function was good. One man was an ex-smoker, having stopped in 1966. His medical file indicated that he suffered from respiratory allergy. There remained one non-smoker whose dust index was among the highest in the study group (262.6). This worker does not seem to present any other risk factor except a high cumulative exposure to asbestos.

Table 4 shows the results of the readings of the fifth reader. Multivariate analysis of small opacity score and presence of pleural change show a statisti-

Table 3 Descriptive information on the workers with chest x ray scored 1/0 or more

No	X ray summary score	Lung functions % predicted	FVC	FEV ₁	Cough and phlegm	Age	Year started work	No of years exposure	Dust f/cc × year	Smoking habit	No of cig/day	Any pleural change (except CA)	Other occupations
A	1-01	78	83	no	61	1959	21	32.5	Smoker	20	1		Plumber, 27 years
B	1-05	80	85	no	47	1956	25	39.3	Smoker	25	1		Truck driver, 5 years
C	1-17	84	95	no	54	1958	23	262.6	Non-smoker	—	0		Hockey player, 10 years
D	1-01	111	119	Allergic reaction	49	1958	22	97.5	Ex-smoker (stopped 1966)	20	0		Construction, 9 years
E	1-79	105	92	yes	53	1960	20	38.5	Smoker	15	0		Construction, 3 years
F	1-14	—	—	no	43	1960	8	55.3	Smoker	20	0		Truck driver, 3 years
G	1-03	92	97	no	40	1967	15	58.1	Smoker	25	0		Upholsterer

Table 4 Prevalence of small irregular opacities and pleural changes according to several variables (fifth reader)

	No of workers	Small irregular opacities 1/0 or more	Pleural thickening			Pleural calcification	Any pleural changes (except CA)
			Diaphragm	Chest wall	Costophrenic angle (CA)		
Overall	331	79 (23.9)	7 (2.1)	25 (7.6)	8 (2.4)	1 (0.3)	29 (8.8)
Age:							
< 40	60	8 (13.3)	0 —	0 —	0 —	0 —	0 —
40-49	149	39 (26.2)	2 (1.3)	8 (5.4)	1 (0.7)	0 —	10 (6.7)
≥ 50	122	32 (26.2)	5 (4.1)	17 (13.8)	7 (5.7)	1 (0.8)	19 (15.6)
Smoking habits:							
Smoker	157	52 (33.1)	4 (2.5)	12 (7.6)	4 (2.5)	1 (0.0)	15 (9.6)
Ex-smoker	118	20 (16.9)	1 (0.8)	9 (7.6)	3 (2.5)	0 —	9 (7.6)
Non-smoker	55	7 (12.7)	2 (3.6)	4 (7.3)	1 (1.8)	0 —	5 (8.1)
Unknown	1	—	—	—	—	—	—
Time since first exposure:							
< 20 years	85	17 (20.0)	0 —	1 (1.2)	0 —	0 —	1 (1.2)
≥ 20 years	246	62 (25.2)	7 (2.8)	24 (9.8)	8 (3.3)	1 (0.4)	28 (11.4)
No of years of exposure:							
< 10	18	3 (16.7)	0 —	1 (5.6)	1 (5.6)	0 —	1 (5.6)
10-19	91	19 (20.9)	0 —	1 (1.1)	0 —	0 —	1 (1.1)
≥ 20	222	57 (25.7)	7 (3.2)	23 (10.4)	7 (3.2)	1 (0.5)	27 (12.2)
Cumulative index of exposure: (f/cc × years):							
< 30	42	9 (21.9)	0 —	3 (7.1)	2 (4.8)	0 —	3 (7.1)
30-89	155	33 (21.3)	3 (1.9)	10 (6.5)	5 (3.2)	1 (0.6)	12 (7.7)
≥ 90	134	37 (27.6)	4 (3.0)	12 (8.9)	1 (0.7)	0 —	14 (10.4)

Table 5 Prevalence of small irregular opacities 1/0 or more according to average fibre exposure and smoking habits (fifth reader)

Smoking habits	Average fibre exposure (f/cc)									
	0-2		3-5		6-9		≥ 10		Overall	
	%	(No)	%	(No)	%	(No)	%	(No)	%	(No)
Smoker	31.8	(66)	31.8	(22)	24.1	(29)	42.5	(40)	33.1	(157)
Ex-smoker	13.7	(51)	17.4	(23)	14.3	(14)	23.3	(30)	16.9	(118)
Non-smoker	6.9	(29)	0.0	(5)	0.0	(6)	33.3	(15)	12.7	(55)
Overall	20.5	(146)	22.0	(50)	18.4	(49)	34.1	(85)	23.9	(330)

cally significant association ($p < 0.001$) between small opacity score, smoking habits, and average fibre exposure ($p < 0.05$), and an association between pleural change and age ($p < 0.001$). Table 5 shows the prevalence of small opacities (1/0 or more) as read by reader 5 according to smoking habits and average fibre exposure. The prevalence changes according to smoking habit and rises sharply above an average exposure of 10 f/cc.

Discussion

In our group of 331 chrysotile miners and millers we recorded a prevalence of 2.1% for small irregular opacities of grade 1/0 or more and 2.7% for pleural changes from a pool of four readers who provided similar prevalence figures. These values were respectively 24.0% and 8.8% according to a fifth reader whose results were therefore analysed separately.

Analysis of the association between exposure indices and radiological changes as ascertained by the first four readers provided essentially negative results. Indeed the frequency of radiological changes showed no statistically significant or increasing trends with duration of exposure, time since first exposure, level of exposure, or cumulative exposure. The analysis of the fifth reader's observations shows a statistically significant association between small opacity score and average level of exposure; associations between other indices of exposure or other radiological signs, or both, were not significant.

Measurement errors are not likely to explain the absence of a relation between radiographic changes and those features of exposure which may be meas-

ured with accuracy, such as duration of exposure and time since first exposure. It cannot be totally excluded, however, that imprecisions in the evaluation of the level of exposure are responsible for some of our negative findings.

As is well known, the objective evaluation of radiological changes is difficult to achieve. It seems unlikely, however, that this would explain our negative findings since we computed a weighted average of the first four readings. Also, the prevalence of pleural changes showed a significant increase with age as would be expected from the results of other studies.²

A comparison of our results with those from other studies of a dose response relationship between exposure to asbestos (mostly chrysotile) and the prevalence of small irregular opacities 1/0 or more within a similar range of exposure is presented in table 6. The figures in the table had sometimes to be estimated from the published data, and the presentation of the results is restricted to those parts of the studies that deal with low cumulative exposure. Even though indexes of exposure were not computed in the same way, we believe that comparisons are still valid because all the studies deal with the same range of exposure. The overall prevalence estimated in the present study is close to the estimates of Rossiter *et al* in the less dusty groups of workers of the Quebec mining industry,⁶ and to the prevalence found by Weill *et al* in an asbestos-cement factory⁷; however, our follow up is two to three times as long. On the contrary, the prevalence found in an asbestos-textile factory, with a comparable duration of follow up is seven times higher. Our data tend to confirm the estimate derived from a

Table 6 Prevalence of small irregular opacities 1/0 or more in different studies

Author	Type of industry	Size of the sample	Range of exposure	Range and average duration of follow up	Prevalence
Rossiter <i>et al</i> ⁶	Mining	3059	< 100 mppcf	One month-45 y 6.0 y	2.5%
Weill <i>et al</i> ⁷	Asbestos-cement	327	< 200 f-y/cc	One month-45 y 9.1 y	2%
Berry <i>et al</i> ⁸	Asbestos-textile	197 (first employed after 1950)	< 100 f-y/cc	10-20 y 16.0 y	14.7%
Present study	Mining	331	< 300 f-y/cc	10-27 y 20.3 y	2.1%

study of Quebec miners exposed to higher concentrations for a shorter time,⁶ of a 2% risk of radiographic changes after exposure to less than 300 f-y/cc in the mining industry. This agrees well with what was found in an asbestos-cement factory.

To our knowledge, no studies have compared the prevalence of radiological changes between groups of exposed and non-exposed workers, using readings of the same pool of readers. To provide some information on this point, we included in the study a group of 29 office workers from other mines. This referent group was believed not to have worked in a dusty environment and had an age distribution similar to that of the exposed workers. These 29 workers, together with the 19 office workers of Lake Asbestos, formed a total referent group of 48 workers. Of this group, one had a small opacity score of 1.54 and another showed pleural changes. This gives a prevalence of 2.1% for both small irregular opacities and pleural changes among office workers, which is close to the overall prevalence in the exposed group. The fifth reader recorded 13 small opacities (1/0 or more) among the 48 office workers (27.1%) and four pleural changes (8.3%), which again is close to his overall prevalence in the exposed group. The proportion of smokers among the office workers was slightly lower than in the exposed group (31% v 47%).

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