

Follow-up respiratory measurements in Quebec chrysotile asbestos miners and millers

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BECKLAKE MR, THOMAS D, LIDDELL FDK, MC DONALD JC. Follow-up respiratory measurements of Quebec chrysotile asbestos miners and millers. *Scand j work environ health* 8 (1982): suppl 1, 105–110. In 1974 changes in dyspnea, lung function, and pneumoconiotic radiographic abnormalities were recorded among the 1,015 Quebec chrysotile miners and millers surveyed in 1967–1968. The aim was to relate these changes to dust exposure — age, smoking, and earlier health status being taken into account. Dyspnea and lung function were assessed in 722 men, and for 277 recent radiographs were read separately by three experts for changes in the parenchyma and pleura. Each measure was analyzed independently for men without any abnormality when first seen (eligible for “attack”) and for others (eligible for progression/regression). Age significantly influenced the rate of attack of pleural abnormality and the rates of attack and progression of dyspnea and lung function decline. Smoking had comparatively minor effects. The only associations with exposure were for progression of parenchymal change (one reader), and for progression of dyspnea. These essentially negative findings are similar to those obtained in a previous longitudinal survey of radiographs from the same workforce.

Key terms: age, asbestos exposure, dyspnea change, lung function change, parenchymal change, pleural change, smoking.

Fibrosis of the lungs (asbestosis) and pleural fibrosis may follow exposure to airborne asbestos dust. Clinical indicators include breathlessness, basal rales, abnormalities of lung function, and certain chest radiographic changes, in particular parenchymal opacities and pleural thickening and/or calcification. The prevalence of such indicators has been reported in several cross-sectional studies of exposed

workers (1, 7), but such prevalences do not give the incidence of abnormality and may underestimate its occurrence because of selective retirement due to ill health. Moreover, none of these clinical indicators, including those derived from the chest radiograph, is specific for asbestosis.

A comprehensive research program into the health effects of exposure to asbestos in the chrysotile mines and mills of Quebec (7) included cross-sectional observations on 1,015 current male workers; it demonstrated associations between exposure and breathlessness on exertion and declines in certain lung functions. For 11,207 current and former workers, parenchymal and pleural radiographic changes were also associated with exposure (7). The present study was undertaken to add serial measurements on the 1,015 men already mentioned. The primary objective was to

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assess the relationship of change over time to occupational exposure — age, smoking, and health status at the first survey being taken into account.

Materials and methods

Subjects

The subjects for the present study (the 1,015 Quebec chrysotile asbestos workers already mentioned) had been selected from a register of current workers (approximately 6,000), as of 31 October 1966, by stratified random sampling weighted towards the older ages. In 1967–1968 each man had completed a questionnaire and performed certain lung function tests; his most recent annual radiograph had also been reviewed (7). The 1967–1968 characteristics of these 1,015 men are shown in table 1 according to their status at restudy in 1974. Ninety-one had died, and 105 were not reexamined for the reasons stated. Of the 97 reexamined by questionnaire only, most were retired, and they were excluded from further analysis. The men reexamined by questionnaire and lung function tests numbered 445; for 277 of them pairs of chest radiographs were also available for review, the first taken within 12 months of the first survey and the second such that the interval between the radiographs was within 15 months of the interval between the survey examinations. Another 83 pairs of radiographs did not meet these requirements and were not included in the analysis. A work history up to 31 October 1966, with start and end dates for each job, had been obtained for each man from the employment records. From these a cumulative exposure index had been calculated in million particles per cubic foot $\times$ years ($\text{mpcf} \cdot \text{yr}$)³ for each man by methods previously described (7). It was not feasible (and, we believe, not important) to update these indices of exposure at the second examination.

³ 1 $\text{mpcf} \cdot \text{yr}$ = 35.31 millions of particles/ $\text{m}^3 \cdot \text{a}$.

Health assessments

To maximize comparability with the 1967–1968 survey results, the same questionnaire was administered by the same interviewer, and lung function was re-measured on the same, similarly calibrated apparatus. Smoking status was as recorded in the 1967–1968 survey; nonsmokers were defined as those who had never smoked as much as one cigarette a day for a year (7). Breathlessness was graded as follows: grade 0 (not short of breath); grade 1 (short of breath when hurrying on level ground); grade 2 (short of breath when walking on level ground); and grade 3 (stops for breath when walking on level ground). Changes of 1 and 2 grades between surveys were regarded as doubtful and definite, respectively. For assessment of the initial lung function status, measurements of maximum midexpiratory flow (MMEF) and forced vital capacity (FVC) were expressed as the percentage predicted with formulas based on a nonsmoking population (8). Change between examinations was assessed as the percentage of the actual initial values recorded: (initial — final)/initial. Variations of up to 10 % were considered as unchanged, 10 to 20 % as doubtful change, and over 20 % as definite change. In keeping with recommended practice (11), three experienced readers working separately evaluated the 277 film pairs, which were interspersed with film pairs from another workforce, also asbestos-exposed, without knowledge of their provenance. After reading the earlier film from each pair according to the 1971 ILO U/C classification (5), the reader then put up the later film and recorded change as: O (no change), L (less), and M (more) on a scale extended as for parenchymal abnormality in the following manner: L/L, L/O, O/L, O/O, O/M, M/O, or M/M. Readings of O/L and O/M were considered as indicating doubtful change, and readings of L/O, L/L, M/O and M/M as definite change.

Analysis

The men were classified separately for each feature into those without abnormality when first seen (eligible for “attack”) and others (eligible for “progression/

regression"). Crude attack and progression/regression rates were calculated with the subjects divided into four exposure groups: < 10, 10–99, 100–199, and $\geq$ 200 mpcf·yr. Trends in relation to exposure were assessed by multiple regression analysis, differences in age and smoking being taken into account. For tests of significance, response (grade of attack and progression/regression) and stimulus variables (exposure, age, smoking) were treated as ordinal. For the estimation of adjusted attack and progression/regression rates, all variables were treated as nominal by use of binary "indicator" variables constrained to an additive model. The procedures were carried out separately for the two groups (with and without chest radiographs), and with the groups combined, variables being added to the test for between-group differences in slopes and intercepts. We also examined the prognostic value of the assessments at the first examination. This analysis was complicated by regression to the mean (the tendency for high values at first examination to fall and vice versa), which may result in apparent relationships between change and initial value even in the absence of a biological relationship (9).

Preliminary analysis had suggested that the phenomenon was present (2). To assess its magnitude, we carried out two multiple regression analyses on the groups combined, one in which changes in dyspnea, MMEF, and FVC were related to the initial values of these three variables adjusted for exposure, age, and smoking, and one in which changes were related to the average values, similarly adjusted.

Results

There was a higher proportion of men eligible for attack in the lower than in the higher exposure groups; this finding was consistent for almost all the features of the men without and with radiographs. Table 2 shows that there were substantial proportions of men showing change between surveys assessed as attack and progression, with rates somewhat higher for men without than for men with chest radiographs. The former were also, on the average, older and had had longer and heavier exposure than the latter (table 1). In addition, for substantial proportions of the

Table 1. Characteristics of the subjects at the first examination (1967–1968) in relation to their status in 1974. Means and standard deviations are given, except for breathlessness and irregular opacities, for which the group prevalence is given.

Characteristics at first examination, 1967–1968	Not reexamined in 1974		Reexamined in 1974		
	Not alive (N = 91)	Not seen ^a (N = 105)	Questionnaire only (N = 97)	Questionnaire & lung functions (N = 445)	Questionnaire, lung functions & chest radiograph (N = 277)
Age (a) ^b	58.3 ± 6.8	42.3 ± 13.2	48.5 ± 12.2	53.0 ± 10.9	41.8 ± 9.5
Employment (a) ^c	28.5 ± 11.7	13.9 ± 10.8	20.3 ± 10.8	23.3 ± 11.8	13.9 ± 9.7
Exposure (mpcf·yr) ^c	326 ± 347	84 ± 158	289 ± 590	343 ± 487	115 ± 254
Breathlessness (%) ^d	42.9	25.9	40.2	35.7	31.8
Irregular opacities (%) ^e	17.6	3.8 ^f	8.6	9.4	4.2
Forced vital capacity (% predicted) ^g	87 ± 20	97 ± 16	94 ± 17	91 ± 17	95 ± 14

^a Forty-five not traced, 32 had moved, 22 refused, 6 were sick when contacted.

^b Age at date of first examination.

^c Employment and exposure calculated to 31 October 1966; 1 mpcf·yr = 35.31 millions of particles/m³·a.

^d Answered yes to the question: Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill?

^e Grade 1/0 or more: average prevalence for six readers (7).

^f Refers to 84 of the 105 men.

^g See previous report for source of predicted values (7).

men, regression was recorded for breathlessness and MMEF, but it was assessed as definite for relatively few men. Little radiographic regression was read.

Because there were no significant differences in slope and intercept between the two groups (without and with chest radiographs) for breathlessness, FVC, and MMEF in relation to the stimuli (age, smoking and exposure), the analysis of

these variables was carried out with the groups combined; the results are shown in table 3 and fig 1. The effect of age was significant for attacks and progression/regression of all three features, and that of smoking for attacks of MMEF abnormality and for progression/regression of FVC abnormality. However the effect of exposure was significant only for progression/regression of breathlessness. For the

Table 2. Attack and regression/progression rates for the different features separately.

Clinical features	Attacks ^a			Regression/progression ^a				
	Number eligible	All (%)	Definite ^b (%)	Number eligible	Regression (%)		Progression (%)	
					All	Definite ^b	All	Definite ^b
<i>Men without chest radiographs (N = 445)</i>								
Breathlessness	181	43.6	19.3	264	35.2	6.4	24.2	9.1
Forced vital capacity	214	42.0	14.4	231	4.7	2.1	48.0	20.8
Maximum midexpiratory flow	221	78.0	59.2	224	17.4	11.6	62.9	50.0
<i>Men with chest radiographs (N = 277)</i>								
Breathlessness	146	26.7	8.3	131	44.2	6.8	16.0	6.1
Forced vital capacity	188	27.7	4.2	89	5.6	1.1	33.7	14.6
Maximum midexpiratory flow	166	66.8	47.5	111	19.8	12.6	55.8	41.4
Parenchyma								
Reader 1	136	34.5	25.0	141	1.4	0.7	36.2	29.1
Reader 2	120	41.6	38.3	157	0.0	0.0	38.2	32.5
Reader 3	105	22.8	17.1	172	0.6	0.6	27.9	25.6
Pleura ^c								
Reader 1	259	7.7	7.7	18	5.5	5.5	11.1	11.1
Reader 2	226	8.9	7.1	51	13.8	13.8	21.5	19.6
Reader 3	242	7.9	7.9	35	2.9	2.9	11.4	11.4

^a Subjects were divided into those eligible for attack and those eligible for regression/progression, each feature being assessed separately. For breathlessness men were eligible for attack if they had grade 0 in the first survey, for lung functions if their values exceeded 85% predicted, and for radiographic change if all readings were 0.

^b For definitions see text.

^c Graded on the basis of whether one or both sides were involved using readings of pleural thickening and/or calcification and ill-defined cardiac outline or diaphragm: grade 0 (all readings 0); grade 1 (any change read confined to 1 side); grade 2 (changes read on both sides); grade 3 (pleural thickening read on both sides, as well as ill-defined cardiac outline and/or diaphragm).

Table 3. Significance of the relationships of age, smoking, and exposure to rates of attack and progression/regression, each adjusted for the other two.^a

Clinical features	Age		Smoking		Exposure	
	Attack	Progression/regression	Attack	Progression/regression	Attack	Progression/regression
<i>All men (N = 722)</i>						
Breathlessness	0.0028	0.017	0.057	0.066	0.069	0.027
Forced vital capacity	0.00002	0.019	0.26	0.043	0.072	0.18
Maximum midexpiratory flow	0.00001	0.0024	0.0035	0.085	0.43	0.22
<i>Men with chest radiographs (N = 277)</i>						
Parenchyma						
Reader 1	0.14	0.34	0.57	0.13	0.12	0.013
Reader 2	0.64	0.068	0.032	0.15	0.18	0.40
Reader 3	0.48	0.19	0.23	0.46	0.15	0.20
Pleura						
Reader 1	0.0046	0.78	0.19	0.40	0.50	0.29
Reader 2	0.0021	0.31	0.21	0.937	0.50	0.60
Reader 3	0.00003	0.70	0.057	0.38	0.90	0.20

^a The table gives one-tailed p-values to two significant figures or five decimal places for the F-tests for each variable adjusted for the other two by multiple regression analysis. p-Values of less than 0.5 indicate positive associations, and those greater than 0.5 negative associations.

277 men with chest radiographs, crude rates for attack by parenchymal and pleural abnormality and for progression of parenchymal abnormality increased with exposure. However, when these rates were adjusted for age and smoking, the contribution of exposure was significant only for parenchymal progression, and only by one reader (table 2 & fig 2).

The relationship of change to average values at the first and second examinations produced results in the directions expected on clinical grounds, namely, that those subjects with a poorer average status also showed greater rates of deterioration. However, the regressions on initial values showed quite different results, each positive relationship being changed to a significantly negative one (as predicted by regression to the mean).

Discussion

In our previous surveys, the cross-sectional prevalence rates were clearly related to past exposure (7), but measures of attack or progression were not (6). The same result was also obtained in the present study, despite the fact that exposure ranged from slight to heavy, and attack and progression rates, while different between features, were nevertheless substantial. The lack of a relationship to exposure contrasted with the demonstrable effects of age and, to a less extent, smoking.

In an earlier longitudinal chest radiograph survey of the same workforce over a 20-a period (6), three main explanations were discussed: (i) inappropriate and/or inaccurate response and stimulus variables, (ii) variations in pattern of attack and progression in a chronic disease process, and (iii) individual characteristics collectively known as "susceptibility." These same possibilities again apply. In addition, the follow-up period of less than 8 a may have been too short for a detection of effects over and above those attributable to ageing. No account was taken of exposure during the period of follow-up, but we do not believe this factor alone could explain our failure to show stronger exposure-response relationships because of the relatively modest contribution of exposures after 1966 compared to those before that date (4). On the other hand, it is possible

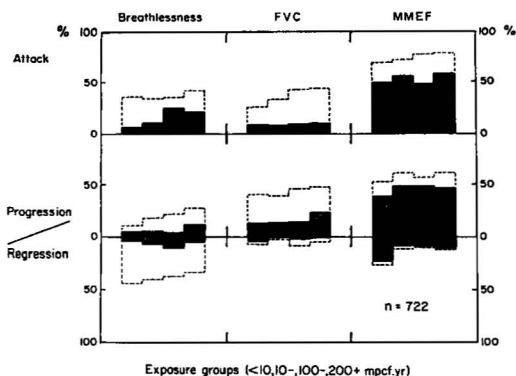


Fig 1. Adjusted prevalence rates for attack and progression/regression of breathlessness, forced vital capacity (FVC), and maximum mid-expiratory flow (MMEF) abnormality in relation to the exposure of 722 men divided into four exposure groups (< 10, 10–99, 100–199, and ≥ 200 mpcf $\cdot$ yr). Doubtful changes (outlined by broken lines) are distinguished from definite and severe changes (solid bars). (1 mpcf $\cdot$ yr = 35.31 millions of particles/ $m^3 \cdot$ a)

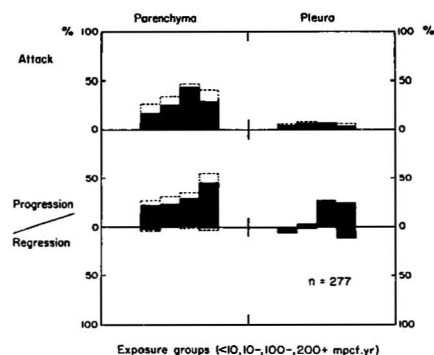


Fig 2. Adjusted rates for attack and progression/regression of radiographic changes assessed by reader 1 in relation to the exposure of 277 men divided into four exposure groups (< 10, 10–99, 100–199, ≥ 200 mpcf $\cdot$ yr). Doubtful changes (outlined by broken lines) are distinguished from definite and severe changes (solid bars). The additive model used for adjustment produced a negative estimate of progression in the exposure group of > 10 mpcf $\cdot$ yr and a positive estimation of regression in exposure group 100–199 mpcf $\cdot$ yr, both of which are shown as 0. (1 mpcf $\cdot$ yr = 35.31 millions of particles/ $m^3 \cdot$ a)

that the effects which we attributed to age in fact reflect residence time of dust in the lung, which, because of the improving environmental conditions, is becoming progressively more strongly linked to ageing. Indeed the exposure-response relationships in various reported prevalence studies (1,

3, 7, 10) may have been largely attributable to the inclusion of workers subjected to very heavy past exposures, which heavily weight cumulative exposure indices. Thus in the modern era, which started in the 1960s for the Quebec mines and mills, exposure (at least as measured in this study) may have become less important, perhaps because it is too crude a reflection of lung dust retention (and burden) or perhaps because other factors, host or environmental, are becoming relatively more important to the determination of outcome.

Acknowledgments

We gratefully acknowledge the cooperation of workers (past and present), unions, and management for allowing us to make this study; the help of Dr F White (Victoria, BC) in the field study; and that of Dr R Jones (New Orleans, LA), Dr R Lilis (New York, NY), and Dr RHL Murphy (Boston, MA) in the reading of the radiographs.

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