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Radiological changes after withdrawal from asbestos exposure

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ABSTRACT A group of 135 ex-employees of the Quebec chrysotile production industry comprising men who were born between 1901 and 1920, who had left the industry between 1950 and 1961, and had been radiographed before leaving, attended in 1972 for a medical examination and further chest radiograph. This report concerns 86 men whose withdrawal film was within 12 months of leaving and who had not been exposed subsequently to asbestos or other fibrogenic dust. Seven separate assessments were made of the paired radiographs, side by side in known temporal order. The assessments were classified as showing 'increase' or 'no change'. In 66 film-pairs from men with two years' employment or longer, at least four assessments were of parenchymal increase in six, of pleural increase in 13, and of both parenchymal and pleural increase in two, total 21 (or 31%). There was similar agreement of no change in 24 pairs (36%), and evidence was equivocal in the remaining 21 pairs. Parenchymal increase was not agreed in any of the 20 film-pairs from men with shorter employment, but pleural increase was seen in four of these men, a proportion similar to that in those exposed longer. We conclude that the parenchymal changes observed after leaving the industry, most of which were 'attacks' rather than 'progression', were attributable to the earlier occupational exposure to chrysotile; there were no important differences in age or smoking habit between those with and without parenchymal change.

Exposure to airborne dusts containing asbestos fibres may lead to depressed lung function, respiratory signs and symptoms, and radiological changes. Of these, small irregular opacities in the parenchyma and pleural thickening on chest radiography are the more specific signs of asbestosis, if not always the first detectable. In many industries it has been the practice to advise a worker, whose periodic chest radiograph shows early pneumoconiosis, to withdraw from further exposure in the hope that this will delay or prevent deterioration. However, although Gilson (1973) stated that 'it is generally agreed that progression occurs without further exposure when asbestosis has reached a degree of severity which permits confident diagnosis', he also remarked that in less severe cases 'it is still not known whether there is functional or radiographic improvement after removal'. The present study was undertaken with two objectives. First, to see whether there was any incidence or progression of pneumoconiotic appearances in men who had not been exposed to asbestos or other fibrogenic dust over a substantial period. Second, to determine whether any incidence or progression observed could have been predicted from the work history, taking into account age and smoking habit

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Materials and methods

The Quebec asbestos mortality study (McDonald *et al.*, 1971, 1974; McDonald and Liddell, 1978) embraces all 11 379 of those subjects born between 1891 and 1920 who worked in the chrysotile-producing industry of Quebec for at least a month. They have been followed from first employment (as early as 1904) to the end of 1975, with a high trace rate (more than 98% of those known to be alive in 1935). A work history, with dates of start and termination of each job, was obtained for each person, and a measure of accumulated exposure to airborne respirable asbestos dust was calculated from assessments of concentration by job and year and expressed in terms of million particles per cubic

foot × years, or mpcf.y (Gibbs and Lachance, 1972).

From this cohort, we identified 381 men still alive in 1972, who had been born after 1900 and who had left the industry for any reason in the period 1950–61. Of these, 287 were residing in accessible districts of the Province of Quebec, and for 260 a full size postero-anterior chest radiograph (the 'withdrawal radiograph') taken somewhere near the time of leaving the industry, was available. We wished to include not only subjects with heavy exposure and radiographic abnormality, in whom progression might have been expected, but also men with light exposure, in whom progression would be less likely. For this reason the 260 men were classified by the reading of the withdrawal radiograph (Rossiter *et al.*, 1972) and by accumulated dust exposure (Table 1),

Table 1 *Radiographic findings and dust exposure in 260 possible subjects*

Accumulated dust exposure (mpcf.y)	*Findings at time of withdrawal radiograph*		
	Negative	*Positive**	*All*
< 10	74	17	91
10, < 100	86†	20	106
100, < 200	15	3	18
200, < 400	16	6	22
400, < 800	9	7	16
800 +	6	1	7
All	206	54	260

*At least one reader (of six) recorded profusion 0/1 or greater of small opacities and/or any pleural change.
†Excluded from study; see text.

and the 86 subjects with negative radiographic findings and with dust exposure between 10 and 100 mpcf.y were excluded, for reasons of economy. We had hoped to examine all those remaining, but failed in 39 cases, because of the subject's illness or refusal or non-attendance despite repeated promises.

We were able to examine 135 men in Montreal and other urban centres in Quebec. The examination consisted of a questionnaire on smoking habits, a request to recall a complete work history, and a full size (14 in × 17 in (≈ 0·35 m × 0·43 m)) p-a chest radiograph. (Although not of concern in this report, the questionnaire also elicited information regarding respiratory symptoms, lungs were auscultated, and lung function was tested.) The questionnaire was that of the British Medical Research Council, adapted as in our previous studies of workers in the Quebec asbestos industry (McDonald *et al.*, 1972). The responses were classified by two of us (FDKL and JCMcD), blind as to radiograph readings, according to current smoking habit as non-smoker, ex-smoker, smoker, or heavy smoker; the latter was defined as one who smoked 30 or more cigarettes a day or an equivalent amount of tobacco.

The reported work histories were compared with those collected previously from personnel records, and in most cases were compatible if not identical. Discrepancies were investigated, and the man's own report led to a few clarifications of the recorded history. In six cases, however, doubts whether the man who had been examined was the same one whose radiograph had been read in 1967 were sufficient to warrant the subject's exclusion. The reported work histories also showed that 14 men had been exposed to asbestos or other fibrogenic dust since withdrawal from the industry; these, too, were omitted. After study of the intervals between actual withdrawal from the industry and the available withdrawal radiograph, we decided to exclude a further 29 subjects for whom that interval was greater than 12 months. This left 86 men who met all our criteria.

For each of these 86 subjects, we calculated the following.

Before the withdrawal radiograph

Gross service: the period from start of first job in the industry to the date of the withdrawal radiograph.

Net service: the total of periods of actual employment, within gross service.

Total dust exposure: the total of annual dust exposures, summed over the period of gross service; the units were mpcf.y.

Between available radiographs

Interval: the period from the withdrawal radiograph to the radiograph in 1972.

Gross service: the period from the withdrawal radiograph to actual withdrawal from the industry, by definition not more than 12 months.

Total dust exposure during any service after the withdrawal radiograph.

The paired films, with identifying information obliterated, were read side by side in known temporal order into the complete ILO U/C 1971 classification of radiographs of the pneumoconioses (International Labour Office, 1972). The more recent film was read first, and then the earlier film. The pairs of films had been assembled into six batches, which were presented to each reader in a different sequence. ILO standard films were available to all readers. Seven assessments of each film-pair were made by eight experienced readers: six worked quite independently; the other two read together, yielding one assessment independent of the rest. The readers were Dr L. J. Bristol (USA)*; Dr P. H. Cartier (Canada)*†; Dr R. G. Fraser (Canada)†; Dr J. C. Gilson (UK)*; Dr T. R. Grainger (Canada)*†; Dr J. C. McDonald (Canada)*†; and, working together

Table 2 *Radiographic change between films*

Site	*Withdrawal radiograph*	*1972 radiograph*	*Evaluation*
Parenchyma*	Any reading	No more than one step higher	No change
	0/– or 0/0	Two or more steps higher	Increase: attack
	0/1 or above	Two or more steps higher	Increase: progression
Pleura	Any reading	The identical reading	No change
	0 for all features	Not all features 0	Increase: attack
	Not all features 0	At least one step higher on any graded feature, or appearance of an additional feature	Increase: progression

*Maximum small opacities, i.e. the higher reading of profusion of small rounded and small irregular opacities.

Drs J. A. Dick and J. S. Washington (UK). The five marked with an asterisk (*) had taken part in our previous studies (Rossiter *et al.*, 1972) and in the development of the UICC/Cincinnati (1970) and ILO U/C (1971) classifications (UICC Committee, 1970; International Labour Office, 1972); only four readers (†) were aware that the subjects had not been occupationally exposed to dust in the interval between the taking of the two films.

Every parenchymal and pleural assessment of a film-pair was classified as either 'no change' or 'increase', the latter subdivided (*a*) as parenchymal or pleural or both and (*b*) as 'attack' or 'progression', as indicated in Table 2. The very few recorded regressions were included as no change which, for reasons discussed later, also embraced assessments of a single-step increase in profusion of small opacities. In this study, increase, either parenchymal or pleural, is taken as 'agreed' if recorded in at least four of the seven assessments; similarly, no change is considered to be agreed if there were at least five such assessments.

The study population of 86 subjects is described in Tables 3 and 4. There were rather more men from the town of Asbestos, Quebec (56%) than from the area of Thetford Mines, Quebec (44%), and the former were heavier smokers. On average, the age at start of service was 30·1 yr, and the interval from then to the time of the withdrawal radiograph was 10·9 yr, making the age at radiography 41·0 yr. The average gross service between this radiograph and actual withdrawal was 0·3 yr, with an imposed maximum of 12 months. The interval from the withdrawal film until the radiograph in 1972 averaged 16·9 yr, so that the average age in 1972 was 57·9 yr. Total exposure up to the withdrawal radiograph ranged from zero to 3542 mpcf.y, with an average of 236 mpcf.y. The average exposure after the first film before actual withdrawal was 3 mpcf.y, but ranged up to 47 mpcf.y.

Table 3 *Smoking habit and mining area*

Smoking habit	*Town*	
	Asbestos (Quebec)	*Thetford Mines (Quebec)*
Non-smoker	2 (4·2)	7 (18·4)
Ex-smoker	8 (16·7)	9 (23·7)
Smoker	24 (50·0)	17 (44·7)
Heavy smoker	14 (29·2)	5 (13·2)
All	48 (100)	38 (100)

Percentages within each column in parentheses.

The distributions of average radiological scores on the withdrawal radiographs (see Table 4 for definitions) were highly skew, the standard deviations being at least as great as the mean scores. In other words, for a high proportion of the men the average score, whether parenchymal or pleural, was close to zero, but several scores reached the maximum level, unity. Despite this variation and the very wide variation in total exposure the correlations between (*a*) the radiological scores and (*b*) two measures of exposure (gross service and the square-root transformation of total dust exposure) were all small, none being greater than 0·25.

Results

The main findings are summarised in Table 5. At least four of the seven assessments were of parenchymal increase in six film-pairs (7·0%), of pleural increase in 17 pairs (19·8%), and of both parenchymal and pleural increase in two pairs (2·3%). Thus there was some agreement that there had been increase in the films of 25 men (29·1%). In 34 film-pairs (39·5%), there was agreed no change: all seven assessments were of no change in 14; six were of no change in 11; and five were of no change in nine pairs. The evidence was equivocal in the remaining 27 pairs (31·4%). Twenty of the men had experienced less than two years of gross service before the withdrawal radiograph (average service: eight months): none of their film-pairs showed agreed parenchymal increase, but four pairs showed agreed pleural increase.

Table 4 *Ages, lengths of service, exposure, radiological scores before withdrawal, and interval between radiographs*

Findings	*Minimum*	*Maximum*	*Mean*	*SD*
Age at start of service (yr)	14·9	47·3	30·1	(8·8)
Before withdrawal radiograph				
Gross service (yr)	0	35·4	10·9	(9·9)
Net service (yr)	0	32·8	8·0	(7·6)
Total exposure (mpcf.y)	0	3542	236	(524)
At time of withdrawal radiograph				
Age (yr)	30·4	54·9	41·0	(5·3)
Average radiological score				
parenchyma (*a*)	0	1	0·23	(0·24)
pleura (*b*)	0	1	0·15	(0·15)
Between radiographs				
Interval (yr)	11·3	25·1	16·9	(3·1)
Gross service (yr)*	−1·0	1·0	0·3	(0·4)
Total exposure (mpcf.y)	0	47	3	(9)

(*a*) If the profusion of both rounded and irregular small opacities was recorded as 0/– or 0/0, that assessment was scored 0. If either form of profusion was recorded 0/1 or higher, the score was taken as 1. The arithmetic mean of the seven scores was taken as the *average parenchymal score*.
(*b*) If all pleural features were assessed as zero by any reader, a score 0 was allocated: the existence of any pleural change was scored 1. The arithmetic mean of the seven scores was taken as the *average pleural score*. A very few of these averages were approximate because of a data processing error, which could have had little effect, and which it was not feasible to correct.
*A negative value means that the earlier film was taken after withdrawal.

Table 5 *Radiographic change*

Findings	*Gross service before withdrawal radiograph*		
	< 2 yr	*2 yr –*	*All*
Number of subjects	20	66	86
Average length of gross service before withdrawal radiograph (yr)	0·7	14	11
Increase agreed (by at least 4 readers)			
Parenchymal and pleural	— (0)	2 (3·0)	2 (2·3)
Parenchymal only	— (0)	6 (9·1)	6 (7·0)
Pleural only	4 (20·0)	13 (19·7)	17 (19·8)
Total	4 (20·0)	21 (31·8)	25 (29·1)
Equivocal	6 (30·0)	21 (31·8)	27 (31·4)
'No change' agreed (by at least 5 readers)	10 (50·0)	24 (36·4)	34 (39·5)
Grand total	20 (100)	66 (100)	86 (100)

Percentages within each column in parentheses.

In Table 6, four groups of men are compared: eight whose film-pairs showed agreed parenchymal increase with or without pleural increase; 17 showing agreed pleural increase only; 27 where assessments were equivocal, and 34 of agreed no change. Differences between these groups in age at the time of the withdrawal film, interval from that radiograph to the second in 1972, and service after the withdrawal radiograph were small and non-systematic. However, of the 38 men who had worked at Thetford Mines, 16 (or 42%) showed change compared with only nine out of 48 at Asbestos (19%) (Table 6, *3). Of the eight non-smokers among the 86 subjects, pleural increase was agreed in five (62·5%, compared with 22·1% in all subjects), but no other association with smoking habit could be found.

The men in whose film-pairs parenchymal increase was agreed, had started their service on average 10 yr earlier than the men in all the other groups (Table 6, *1) and, as a result, had given longer gross service. Their total dust exposure had also been considerably greater on average than that in the other groups; although their net service was only about one-third longer, they had worked in higher dust concentrations.

About a third of the agreed parenchymal increases could be considered progression from a less than normal withdrawal radiograph (Table 6, *2); about 85% of pleural increases were in the nature of attacks (Table 2). There was no suggestion that pleural increase was related to any measure of dust exposure.

Discussion

At face value, our results indicate that a substantial proportion (9·3%) of men showed an increase in parenchymal small opacities after withdrawal from asbestos exposure. As the increases were confined to the more heavily exposed group and were not explained by differences in age and smoking habit, it suggests to us that they were attributable to their work. However, other factors, such as environmental pollution in the mining areas, cannot be ruled out because they were not examined. Two questions still follow: first, were the radiological increases the results of actual changes in the parenchyma or simply caused by differences in radiographic technique; second, were the increases more than would

Table 6 *Radiographic change in relation to service, exposure, age and radiological scores*

Findings	*Increase agreed by at least 4 readers*				*Equivocal*		*No change agreed by at least 5 readers*
	Parenchymal		*Pleural*				
Number of subjects	8♣		17		27		34
From Asbestos	3		6		17		22
		9				39	
From Thetford Mines	5		11		10		12
		16				22	
Proportion at Thetford Mines	62%		64%		37%		35%
		64%		(*3)		36%	
Non-smokers	2♣		3		2		1
Age at start of service (yr)	21·0	(*1)	31·4		31·9		30·2
Before withdrawal radiograph							
Gross service (yr)	20·0		9·5		10·1		10·0
Net service (yr)	10·3		8·0		7·8		7·5
Total exposure (mpcf.yr)	498		149		262		197
At time of withdrawal radiograph							
Age (yr)	41·0		41·0		42·0		40·2
Average radiological score							
Parenchymal; see (*a*), Table 4	0·36	(*2)	0·21		0·37	(*4)	0·11
Pleural; see (*b*), Table 4	0·23		0·20		0·20		0·08
Between radiographs							
Interval (yr)	15·6		17·2		17·1		16·9
Gross service (yr)	0·4		0·3		0·3		0·4

* P value for difference between adjacent columns: (*1) 0·003; (*2) 0·015†; (*3) 0·016; (*4) 0·000004.
♣ Including 2 film pairs in which pleural change was also agreed.
† After allowing for intercorrelations in contrast (*1).

be expected in the usual lag period between inhalation of dust and radiological appearance of disease?

Were we planning this study again, we would certainly take more seriously the question of radiological technique, although to have achieved full comparability over up to 25 years between radiographs would not have been easy. Because of this problem, we adopted a conservative approach to the definition of parenchymal increase; namely, that there should be a difference of at least two steps on the 12-point scale of profusion. Moreover, as the readings were made side by side in specified temporal order, the readers were in a position to recognise differences in technique and to allow for them. It was evident from their comments that they did so, but we do not know how well. Side by side reading has the disadvantage, of course, that the reader may be influenced by what he believes about the relation between the films, and so may introduce preconceptions into his reading. The readers varied in their knowledge of the provenance of the films, but all were completely ignorant of the exposure history of each subject; furthermore, they assessed all 135 film-pairs of the men examined. For these various reasons, we are satisfied that the parenchymal increases observed are not attributable to technical differences or other bias.

The second question is more difficult to answer. As we had only two films for each man we cannot distinguish a pattern of parenchymal change, confined to the first few years after withdrawal, from one of continuous progression. It would be necessary to have at least two observations on each subject after withdrawal, the first preferably at about five years after the end of exposure. It has been suggested that a comparison of the present series with a group of workers, matched in age and work history but who had continued employment in the industry, might be informative. It is difficult to see how appropriate allowance could be made for the effects of subsequent dust exposure in the comparison group unless, of course, they fared no worse than those who had left.

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