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RADIOLOGICAL CHANGES IN VERMICULITE WORKERS EXPOSED TO TREMOLITE

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Abstract—Complementary radiographic studies were conducted independently by groups from McGill University and NIOSH among employees of a Montana mine where the vermiculite ore is contaminated by amphibole fibres. In the McGill study, 173 current and 80 past employees were X-rayed in 1983. The x-rays were read by three experienced readers using the ILO (1980) classification. In the NIOSH study, the most recent routinely taken chest x-rays from 184 men who were employed 5 years or more and at some time since 1975 were similarly classified by three qualified readers. In the McGill studies, prevalence of small parenchymal opacities ($\geq 1/0$), pleural thickening on the chest wall and pleural calcification were 18.4%, 27.9% and 11.9%. The corresponding figures from NIOSH were lower at 9.8%, 13.0% and 3.8%. Both studies found small opacities to be independently related to age, smoking and fibre-years. The increase in prevalence of small opacities at age 65 following exposure to 100 f.y. predicted from the McGill and NIOSH studies were similar, at 7.3% and 5.2%. The relationship between pleural changes and fibre-years was weaker and reached statistical significance in the McGill study only.

INTRODUCTION

COMPLEMENTARY RADIOGRAPHIC studies were conducted independently and in parallel by groups from McGill University and NIOSH among past and present employees of a Montana mine and mill where vermiculite ore is contaminated by amphibole fibres, mainly of the tremolite-actinolite series. Full results from these, and companion mortality studies (see AMANDUS *et al.*, 1988 in this volume) will be published independently by McGill and NIOSH elsewhere. Here we compare results from the two radiographic studies.

MATERIAL AND METHODS

In the McGill study, all current workers (164 men and 9 women) on July 1st, 1983, together with 80 out of the 110 past male employees resident within 200 miles of the mine were X-rayed by a standardised technique. The past employees were surviving members in the McGill mortality cohort, the criteria for inclusion being employment of at least one year and date of hire before 1963. The 253 X-rays, mixed with 47 additional films from unexposed subjects (taken by the same standardised technique) were read by three experienced readers using the ILO (1980) classification. X-rays for the nine women, which showed no abnormality, were excluded from further analyses.

In the NIOSH study, the most recent routinely taken chest X-rays still available in the files of the local hospital from 184 of 191 men employed 5 years or more and at some time since 1975 were similarly classified by three readers.

Cumulative exposures in fibre-years (f.y.) at the time of X-ray were estimated in each study from all available measurements made by governmental agencies and the company since 1956. Mean estimated cumulative exposure, net service and age are shown for each study group in Table 1. The higher mean estimated cumulative exposure from the NIOSH study is due in part to the longer mean net service and in part to the higher estimates of exposure in the past made by NIOSH. The McGill study group was on average some four years older than the NIOSH group.

Readings from the three readers were combined as a median, and the relationship between X-ray changes and exposure to fibrous dust was investigated in both studies through tabulations of changes by cumulative exposure group and by logistic regression analyses. The logistic regression model, in which the logarithm of the odds of a subject being radiographically positive is linearly related to the amount of exposure and to levels of possible confounding factors such as age and smoking, is used increasingly for epidemiological analyses (KLEINBAUM *et al.*, 1982).

RESULTS

Prevalence rates for small (mainly irregular) parenchymal opacities ($\geq 1/0$), pleural thickening (plaques or diffuse) on the chest wall, and pleural calcification, are given for each study in Table 2. Small opacities and pleural thickening of the chest wall were read about twice as frequently in the McGill study, and pleural calcification about three times as frequently.

TABLE 1. DESCRIPTION OF STUDY GROUPS

	McGill	NIOSH
Number of men	244	184
Mean age (years)	48.0	44.4
Mean estimated cumulative exposure (f.y.)	65.9	119.4
Mean net service (years)	10.7	14.4

TABLE 2. PREVALENCE OF X-RAY CHANGES
(Median Score)

	McGill (n = 244)		NIOSH (n = 184)	
	Number of positives	Prevalence %	Number of positives	Prevalence %
Small opacities ($\geq 1/0$)	45	18.4	18	9.8
Pleural thickening on chest wall	68	27.9	24	13.0
Pleural calcification	29	11.9	7	3.8

In both studies prevalence of both small opacities and pleural thickening of the chest wall was strongly associated with fibre-years (Table 3). These prevalences were also strongly associated with age, which is highly correlated with fibre-years so that an independent effect of exposure cannot necessarily be inferred from this table. Further tabulations from each study (not shown here) of prevalence of changes by fibre-years after stratifying by age suggest that the relationship of exposure with small opacities cannot wholly be explained by age, but with pleural changes this is less clear. The effect of exposure on X-ray changes, with allowance for confounding effects of age and smoking, has been investigated more formally in both studies using logistic regression. These analyses show that prevalence of small opacities was independently related in both studies to age, smoking and fibre-years. All these relationships reached statistical significance ($p < 0.01$) except that with smoking in the NIOSH study. Prevalence of pleural thickening of the chest wall was also significantly related to age ($p < 0.001$) in both studies but to fibre-years ($p \approx 0.02$) in the McGill study only and to smoking in neither study ($p > 0.10$). The logistic regression equations for the prevalence of small opacities (p), including age and fibre-years, estimated from the two studies were:

$$\text{McGill: } \text{Log}(p/[1-p]) = \eta = -5.93 + 0.079(\text{age in years}) + 0.0033(\text{fibre-years})$$

(standard errors: 0.93 0.016 0.0011)

$$\text{NIOSH: } \text{Log}(p/[1-p]) = \eta = -9.6 + 0.131(\text{age in years}) + 0.0026(\text{fibre-years})$$

(standard errors: 2.1 0.036 0.0009)

Predicted prevalence p may be estimated from the above equations using the formula: $p = 1/[1 + \exp(-\eta)]$.

TABLE 3. PREVALENCE OF RADIOGRAPHIC CHANGES BY EXPOSURE

Exposure group (f.y.)	n.	McGill Study			n.	NIOSH Study		
		Small opacities %	Pleural * thickening %	Pleural calcification %		Small opacities %	Pleural * thickening %	Pleural calcification %
<15	119	10.1	19.3	7.6	63	0.0	6.3	1.6
15<30	37	18.9	16.2	8.1	29	3.4	3.4	0.0
30<85	51	17.6	43.1	19.6	44	6.8	13.6	6.8
≥85	37	45.9	45.9	18.9	48	29.2	27.1	6.3
All	244	18.4	27.9	11.9	184	9.8	13.0	3.8

* on chest wall

TABLE 4. PREVALENCES OF SMALL OPACITIES PREDICTED IN MEN AGED 65 BY LOGISTIC REGRESSION ANALYSES

Cumulative exposure (f.y.)	0	10	50	100	500
Predicted prevalence (%)					
McGill	30.5	31.2	34.0	37.8	69.1
NIOSH	25.3	25.8	27.8	30.5	55.4

The lower intercept (hypothetical prevalence of small opacities at age zero) in the NIOSH study is balanced by a steeper increase of prevalence with age, so that both regression equations predict the same prevalence in an unexposed man aged 70 years. The coefficient for fibre-years is slightly higher in the McGill study. Table 4 shows the prevalences of small opacities predicted in men aged 65 by the above logistic regression equations. For example, according to the models, a working life involving 100 f.y. would entail an increase in prevalence of small opacities at age 65 of about 7.3% (SE 2%) according to the McGill results and 5.2% (SE 2%) according to the NIOSH results.

DISCUSSION

The main difference in the results from the two studies is the 2-3 times higher overall prevalence of X-ray changes in the McGill study. The McGill results also gave a slightly larger regression coefficient for fibre-years, thus predicting an increase in prevalence of small opacities slightly greater than that predicted from the NIOSH results. These differences are likely to have been caused partly by the differences in methods used and partly by the differences in the subjects studied.

The films for the McGill study were recently taken by a standardised technique and 56% were rated by the McGill readers as being of 'good' quality, compared with 22% of 67 films taken from the same source as those used in the NIOSH study and also read by the McGill readers. This difference in quality could well explain much of the difference noted above. Both studies used three experienced readers and one of these was common to the two. Of 135 men included in both studies, the common reader read 30 small opacities ($\geq 1/0$) from the X-rays used by McGill and 23 from those used by NIOSH (16 read as positive in both studies, 14 in the McGill study only and 7 in the NIOSH study only). This is consistent with the hypothesis that the superior film quality in the McGill study resulted in a more sensitive test for abnormality. However, the higher predicted prevalence of opacities in men with zero exposure suggests that this gain in sensitivity was bought at the expense of a loss in specificity.

The slightly greater age of the McGill study group may also explain some of the difference in overall prevalence of X-ray changes, though the longer net service in the NIOSH group would tend to counteract this effect. More importantly, the NIOSH study used only films taken since 1975 of men while still at work at time of X-ray, whereas the McGill group included men who had left before that date, with X-rays all taken in 1983. Men whose X-ray changes only developed after leaving employment would therefore have been read as positive in the McGill but not the NIOSH study. Progression of X-ray abnormalities between the dates of the NIOSH X-rays (1975-82) and those of the McGill X-rays (1983) is unlikely to account for much of the observed difference, since 73% (134/184) of the NIOSH X-rays were taken in the two years before 1983, and the maximum time gap was only eight years.

The predicted increase in prevalence of small opacities at age 65 per unit exposure was remarkably similar in the two studies (e.g. 7.3% from McGill and 5.2% from NIOSH results after 100 fibre-years). The slightly higher McGill figure may be partly due to the factors discussed above and also the lower estimates of exposure made for the McGill study. Comparisons of results with those from other radiographic studies must be cautious, since differences in radiographic technique, readers, and selection of

study population have effects which are unquantifiable. Certainly overall prevalences of changes suggestive of fibrosis are higher in these vermiculite miners than in other blue collar workers not exposed to fibres who have been studied (PETERSEN and CASTELLAN, 1984). The most comparable data for fibre-exposed workers are from a study of past and present miners and millers of chrysotile from Quebec (MCDONALD *et al.*, 1984). In this study, which used one of the three readers in the McGill study of vermiculite miners, a 4% excess small opacities was predicted to result from 100 fibre-years of exposure, slightly lower than in the current studies.

At present, exposure levels in the Libby operation are reported by the Company to average 0.1 f/ml. The excess of radiological change predicted by the McGill and NIOSH studies to result from a working life of 50 years at this level would be about half a percent (an odds ratio of about 1.02). The imprecision associated with radiological technique and reading error is far greater than this level of risk.

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