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Case-Referent Survey of Young Adults with Mesothelioma: II. Occupational Analyses

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Objectives: Our study aimed to identify occupations at increased risk of developing mesothelioma in persons aged 50 yr or less, and to relate these occupations to lung tissue concentration of asbestos fibres by type. In this age group it was thought that most, but not all, work-related exposures would have been since 1970, when the importation of crocidolite, but not amosite, was virtually eliminated.

Methods: Eligible cases were sought from recent reports by chest physicians to the SWORD occupational disease surveillance scheme. Work histories were obtained for 115 men and 13 women, usually with the help of the chest physicians or coroners. Jobs were coded by the Office of National Statistics, so that the observed years spent in each occupation could be compared with expected values from census data, 1960–90. Lung tissue samples were obtained at autopsy from 69 male and four female cases, and mineral fibres identified, sized and counted by electron microscopy.

Results: Of 37 industrial occupations analysed, odds ratios were significantly raised in eight: five in the construction industry and the others in shipbuilding, the manufacture of cement products and the manufacture of non-metallic mineral products (including asbestos). The concentrations in lung of crocidolite and amosite fibres, which together could account for 80–90% of cases, did not differ between occupational categories; those for amosite were appreciably higher than for crocidolite. Tremolite fibres were rarely found.

Conclusion: Mesothelioma in this young age group is dominated by carpenters, plumbers, electricians and insulators in the construction industry, and is mainly attributable to amphibole exposure. Work in shipbuilding and manufacture of mineral products was less important than in earlier studies. Contrary to expectation, however, some 90% of cases were in men who had started work before 1970.

Keywords: mesothelioma in young adults; occupation; lung fibre analysis

INTRODUCTION

The steady rise in mortality from mesothelioma in Britain since the 1950s, predicted to continue for some years to come, was investigated in the present study in persons, so far as possible, aged 50 yr or less at time of diagnosis. It was argued that the occupations and lung fibre content of these cases would mainly reflect potential exposure to asbestos since 1970. By that date the importation of crocidolite, but not amosite, had been virtually eliminated, and stricter controls were in force through the Asbestos Regulations 1969. The use of crocidolite had already tailed off during the 1960s, but some exposure continued after 1970 during building maintenance and asbestos treatment and removal.

Since 1989, the Surveillance of Work-related and Occupational Respiratory Disease scheme (SWORD) has provided a consistent estimate of the incidence of occupational respiratory disease in the UK (Meredith *et al.*, 1991). Some 85% of all consultants in respiratory and occupational medicine throughout the country have reported new cases of occupational respir-

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atory disease on a voluntary and confidential basis, including mesothelioma whether considered occupational or not. All cases of malignant mesothelioma reported by chest physicians to SWORD between 1990 and 1996, born from 1943 onwards, were selected for the study. A later date than 1943 would have been preferable, but would have resulted in too few cases for analysis.

The investigation has two separate but related components. The first entailed identification of eligible cases, followed by detailed recording of work histories and other relevant data. The second required collection of lung tissue at autopsy from as many of these cases as possible, for electronmicroscopic analysis of lung fibre burden, together with samples for comparison from accidental or sudden cardiac deaths. In the latter study, substantially higher concentrations of all asbestos fibres, all amphiboles, crocidolite and, although rarer, tremolite were found in cases than controls (McDonald *et al.*, 2001, this issue). Crude odds ratios reflected these differences, with large values for all groups and concentrations of crocidolite, amosite and all amphiboles, increasing with concentration. The odds ratios for tremolite were also elevated, but of limited statistical significance. It was clear that almost all cases could be explained by amphiboles, but as chrysotile fibres do not persist in lung tissue, their contribution is less certain.

METHODS

Case ascertainment

All reported cases of mesothelioma which met the birth date requirements were identified in the SWORD records. With the agreement of the reporting consultant, a research assistant (HML) visited to obtain a full occupational history with his or her help, using medical records. Where necessary, further information was sought from the coroner and occasionally from the patient's general practitioner. In three cases with no available work history, the patient was visited by a research physician (DJR), after obtaining the consultant's, general practitioner's and patient's consent.

Of 180 eligible cases, 18 had been reported twice, 14 were too old, five were overseas and, in three, the diagnosis had been changed to benign pleural disease, inflammatory disease or adenocarcinoma, leaving 140 (126 men and 14 women) suitable for study. Of these, no work history could be found for 11 men and one woman. The latter had as a child lived very close to a large factory which processed crocidolite, where her father worked. Her illness had been officially designated as attributable to environmental asbestos exposure.

Analysis of work histories

There were thus 115 men (mean age 47, interquartile range 44–49) and 13 women (mean age 42, interquartile range 37–46) available for the occupational analysis. Work histories were recorded, with industry and occupation for each job (up to 16 per patient). These were tabulated and sent for independent coding to the Office for National Statistics (ONS). Observed and expected person-years by occupation were then calculated for the three-year period 1958–60 and for the quinquennia 1961–5, 1966–70, 1971–75, 1976–80, 1981–85 and 1986–90 by indirect standardisation as follows:

Observed. The recorded history and occupation for all recorded jobs of the 115 men were coded using the Standard Industrial Classification 1992 (SIC92) (Central Statistical Office, 1992) and the Standard Occupational Classification 1990 (SOC90), (Office for Population Censuses and Surveys, 1992) respectively. This was done independently by members of the Office for National Statistics (ONS). Codings were then condensed into the major classification of the SIC92 (such as construction and metal processing).

A matrix was constructed with each case contributing to each quinquennium for each job in that period. Where one person had had more than one job, and the starting and finishing dates were unclear, it was assumed that the jobs were of equal length. Any bias resulting from this assumption would tend to underestimate an association between any particular occupation and mesothelioma.

Each man's career lasted n years, starting in the year of his sixteenth birthday and ending in the year he was reported to SWORD as a case. Each year contributed an equal fraction ($1/n$) to the analysis. The fractions for all cases in each industrial grouping in each quinquennium were added together for the period up to 1980, to give the 'observed' total used in Table 1.

Table 1. Observed and expected man-years of employment, by occupation

Industry	Occupation	O/E	(95% CI)
Construction			
	Carpenters	8.9	(7.2–11.0)
	Plumbers	8.1	(6.1–10.6)
	Electricians	5.0	(3.4–7.1)
	Insulators	3.4	(2.5–4.5)
	Unskilled	1.9	(1.4–2.6)
Ship and boat building		6.3	(4.7–8.4)
Mfr. cement products		5.7	(2.1–12.5)
Mfr. non-metallic mineral products (including asbestos)		2.8	(1.3–5.4)
Mfr. glass products		2.1	(0.8–4.5)
Electricity generation		1.5	(0.8–2.6)
Mfr. brick and ceramic products		1.4	(0.5–3.1)
Construction — other trades		1.1	(0.8–1.6)
All other occupations (n=25)		<1.0	–

Expected. As industrial codings have remained much more similar during 1980 and 1990 than those for occupation, it was easier to group denominators into industrial than occupational categories, so the latter were used in analyses.

Census data from 1960, 1970, 1980 and 1990 were used to calculate the expected distribution of employed workers by region and industry. Data were available by age for each of these censuses, and only those age groups required for a cohort born between 1943 and 1965 were selected. For years between the censuses, distributions were calculated assuming a linear trend (for example, the proportion in each industrial group in 1961 was calculated as [0.9×proportion in 1960] + [0.1×that in 1970]). The expected distribution was summarised for each quinquennium as a percentage for each industrial group, and multiplied by the total 'observed' (for all industries) to give the 'expected' total for each industrial group. Observed/expected (O/E) ratios were then calculated for each industrial group by quinquennium. Further analyses were carried out to allow for time spent in each job, and greater weighting given to the earliest exposures; this produced similar results, confirming the general belief that recent exposures have little effect or mesothelioma risk.

Certain major industrial groups — manufacture of non-metallic mineral products not elsewhere classified; manufacture of transport equipment; electrical, gas and water supply; and construction — were all seen to be over-represented among workers with mesothelioma, so the analysis was repeated with these major groups broken down into their subgroups. For the first three categories, this was straightforward, but the denominator data available for 1960 and 1970 for the fourth group (construction workers) could not be subdivided. However, an estimate was obtained from Census economic activity tables kindly supplied by ONS which showed the *occupational* distribution for construction workers, though without breakdown by age. It was therefore assumed that the distribution of occupations was the same regardless of age. A limitation of this analysis was that the denominator for insulation workers included an unidentifiable number in other skills.

The methods for acquiring lung tissue samples and for performing the electronmicroscopic mineral fibre analyses are described in detail elsewhere (McDonald *et al.*, 2001, this issue).

RESULTS

Men

The distribution of observed (O) and expected (E) values in years employed are summarised in Table 1 in descending order of estimated risk. Of the 37 industrial groups or subgroups analysed, odds ratios were significantly raised (as judged by confidence intervals) in eight, five of which were in the construction industry. A further four groups had raised odds ratios, but with confidence intervals which included 1.0. A detailed tabulation showing observed and expected values for all 37 groups in seven periods, 1958–60 and six subsequent quinquennia, 1961–90, can be obtained from the authors on request.

Most of the occupational groups at risk, especially the eight identified above, were clearly associated with possible asbestos exposure: the converse is true of the remainder. Construction, shipbuilding and the manufacture of cement and non-metallic mineral products carried the highest evidence of risk, and together accounted for almost all the male cases. Contrary to expectation, however, 90% of the cases studied were in men who had started work before 1970, and mainly before 1965.

Women

Of the 13 women with a work history, only one had a clear record of occupational asbestos exposure, but another had been a paint sprayer, another a machine operator, and one of the sales assistants had worked in a textile warehouse. The remaining nine women (seven in teaching, nursing or office work, and one each in glass bottling and retail sales) had worked in jobs not obviously entailing exposure to asbestos. No further systematic analysis was made of the female work histories, but see below in relation to lung tissue analyses.

Occupation and fibre content

The relation between occupation and lung fibre content is shown in Table 2, limited to amphibole fibres and to male cases with lung analysis at autopsy. As some of the men had worked in more than one type of occupation, the total number in classified occupational categories (94) is greater than the total number of cases (69).

Although the number in any given occupation is small, the distribution of fibre concentrations in them all is remarkably similar, both for crocidolite and for amosite, although with higher concentrations overall than for crocidolite. All these values for mesothelioma cases are appreciably higher than in controls, particularly at ≥1 f/μg. The data for tremolite, although too scanty for interpretation, appear to follow a similar pattern.

Lung tissue was obtained for analysis from only four of the 13 cases in women. In one of these, 1.8 f/μg of crocidolite was found. She had worked mainly in retail sales (see above) but also, for two periods of five months, as a stewardess on ships calling at South African ports, and was exposed to clouds of asbestos dust during loading. In two other women amosite fibres were detected; one with 0.7 f/μg, employed most of her life in glass bottling, had been exposed for two years to asbestos packing material used in the bottle cartons. The third case, with 0.1 f/μg, had

Table 2. Occupation and amphibole fibre concentrations in lung

	n*	Crocidolite		Amosite		Tremolite	
		Any	≥1f/μg	Any	≥1f/μg	Any	≥1f/μg
Construction work							
Plumbers	15	11 (73%)	3 (20%)	13 (87%)	9 (60%)	4 (27%)	0 (–)
Carpenters	10	5 (50%)	1 (10%)	9 (90%)	9 (90%)	4 (40%)	1 (10%)
Electricians	6	3 (50%)	2 (33%)	5 (83%)	3 (50%)	0 (–)	0 (–)
Insulators	12	10 (83%)	3 (25%)	11 (92%)	6 (50%)	1 (8%)	0 (–)
Unskilled	12	6 (50%)	3 (25%)	10 (83%)	8 (67%)	3 (25%)	0 (–)
Ship/boat building	12	5 (42%)	1 (8%)	9 (75%)	4 (33%)	3 (25%)	0 (–)
Cement/non-metallic mineral products	5	4 (80%)	2 (40%)	5 (100%)	3 (60%)	3 (60%)	0 (–)
None of the above	22	14 (64%)	4 (18%)	16 (73%)	7 (32%)	2 (9%)	0 (–)
All cases	69	41 (59%)	14 (20%)	56 (81%)	33 (48%)	14 (20%)	1 (1%)
All controls	57	9 (16%)	1 (2%)	23 (40%)	5 (9%)	6 (11%)	0 (–)

*Number of men ever employed in the occupations specified.

worked only in clerical or administrative jobs, with no recorded asbestos exposure.

DISCUSSION

This epidemiological study of mesothelioma is perhaps the first to include both occupational and lung burden components in the same investigation of a nationally representative series of recent cases within a narrow and informative age range. It was facilitated — indeed, made possible — by the existence of the SWORD surveillance scheme and the full participation of the country's chest physicians. The study was greatly simplified by deriving expected values for years employed in all recorded occupations from age-specific, regional census data, 1960–90. A very large control series would otherwise need to have been selected and interviewed; an expensive, ethically difficult and time-consuming task. It should be appreciated nevertheless that this approach to risk estimation is limited to a comparison of person-years, and allowed no consideration of duration of employment in any given job.

Despite the steadily rising mortality from mesothelioma, especially among men, it was important to confirm that there remained little evidence of detectable risk outside a few well-recognised occupations. Confirmation of this does not imply that there are no environmental or household cases, or that there is no risk in other industries, but in magnitude it appears lower than had been feared. Previous population-based surveys of mesothelioma, predominantly in much older subjects (McDonald, 2000), generally found most cases and highest risks in shipyard work and in asbestos manufacturing and use, particularly for heat insulation.

Clearly, this pattern would change with the disappearance of the main asbestos industries and the great post-war increase in construction work, the first evidence of which would be seen in the age group we studied. The virtual elimination of crocidolite use before and since 1970, balanced by an enormous increase over the same period in the importation of amosite, mainly for the construction industry, would also be expected to affect the epidemiological picture. It is not surprising therefore to find amosite relatively more prominent than in past studies in the UK (Berry *et al.*, 1989). Regrettably our findings suggest that crocidolite was still important in this young age group, probably because almost all cases were in men who had started work in the 1960s, and also because opportunities for crocidolite exposure continued in the 1970s, as a result of asbestos removal.

Although construction workers have, since the 1960s, dealt increasingly with amosite-containing products, most of their exposure would have been to chrysotile, probably contaminated by some tremolite. Nevertheless, the lungs of our young cases almost all contained crocidolite or amosite fibres, seldom tremolite, with odds ratios related to retained dose in a manner suggesting that commercial amphiboles, rather than chrysotile with or without tremolite, were the cause of most cases. Because of the lack of persistence in lung tissue of chrysotile, a finding based on lung fibre analysis cannot fully define the role of chrysotile *per se*. However, the data suggest that despite widespread use of chrysotile, it probably accounted for few cases of mesothelioma.

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