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Malignant Mesothelioma and Occupational Exposure to Asbestos: an Analysis of 1445 Cases

K. J. BUTNOR[1]*, A. SHARMA[2], T. A. SPORN[1] and V. L. ROGGLI[1]

[1]*Department of Pathology, Box 3712, Duke University Medical Center, Durham, NC 27710;*
[2]*Department of Pathology, Georgetown University, Washington, DC 20007, USA*

Asbestos exposure is indisputably associated with the development of malignant mesothelioma (MM). However, relatively few studies have correlated the manner of exposure with asbestos fiber content and type. We report findings from 1445 MMs with known exposure histories, including fiber burden analyses performed in 268 cases. A total of 1445 histologically and immunohistochemically confirmed cases of MM were placed in 23 categories, according to the predominant manner of asbestos exposure. Asbestos body counts were determined by light microscopy. Asbestos fiber content and type were assessed using scanning electron microscopy and energy dispersive X-ray analysis. Ninety-four percent of cases fell into 19 of the 23 exposure categories. Six occupational categories, including pipefitter, boilermaker, machinist, electrician, maintenance worker and sheetmetal worker, as well as one para-occupational (household contact) exposure category, were represented. Twelve categories reflected the kind of industry in which exposure occurred. These included insulation, shipbuilding, railroad, oil/chemical, paper mill, US Navy, molten metal, glass/ceramic, power, automotive, asbestos manufacture and construction. Elevated levels of commercial amphibole fibers were identified in all 19 categories. The highest levels were identified among insulation and asbestos manufacturing industries and pipefitters. The median value of non-commercial amphibole fibers exceeded commercial amphibole fibers in four categories (automotive industry, household contacts, building occupants and environmental exposures). Multiple exposure categories were identified in one-quarter of cases. The majority of MMs in the USA fall into a limited number of exposure categories, with overlap of categories in a substantial proportion of cases. For most exposure categories, commercial amphiboles are the predominant fiber type.

Keywords: asbestos; malignant mesothelioma; occupational exposure

INTRODUCTION

The association between malignant mesothelioma (MM) and prior asbestos exposure is undisputed. A wide variety of occupational and environmental exposures have been implicated as the source of this exposure. Although numerous reports document MM risk associated with particular exposures, relatively few studies have examined the distribution of occupations in a large series of MM cases.

MATERIALS AND METHODS

In order to investigate the types of exposures related to the development of MM, we reviewed all MMs in one of the author's (V.L.R.) consultation files for which information was available regarding occupation or manner of asbestos exposure. Patients were classified as being employed in one of 12 industries and/or seven occupations, or into one of four non-occupational exposure groups (Tables 1–3). A substantial number of cases had exposure in more than one category. However, an attempt was made to place patients in a predominant category where the most intense exposure probably occurred. Fiber analyses were performed on formalin-fixed or paraffin-embedded lung tissue using previously described methods (Roggli *et al.*, 1992). Lung tissue was processed for digestion using the sodium hypochlorite digestion technique and analysis was performed by light microscopy, as well as scanning electron microscopy and energy dispersive spectrometery. The results were compared with lung tissue from 19 controls who had no evidence of asbestos-related disease and no history of asbestos exposure.

*Author to whom correspondence should be addressed.
Tel: +1-919-970-4918; fax: +1-919-681-7377.

Table 1. Malignant mesothelioma cases by industry

	Single	Multiple	Total
Shipbuilding	203	86	289
US Navy	91	84	175
Construction	99	35	134
Insulation	92	11	103
Oil and chemical	78	10	88
Power plant	50	10	60
Railroad	37	16	53
Automotive	24	27	51
Steel/metal	33	10	43
Asbestos manufacturing	34	5	39
Papermill	7	0	7
Ceramics/glass	6	0	6

Table 2. Malignant mesothelioma cases by occupation

	Single	Multiple	Total
Pipefitter	159	28	187
Boilermaker	81	31	112
Maintenance	75	15	90
Machinist	62	27	89
Electrician	59	22	81
Sheetmetal	17	5	22
Other asbestos	23	0	23

Table 3. Malignant mesothelioma cases with non-occupational exposures

	Single	Multiple	Total
Household contacts	86	3	89
Building occupants	17	1	18
Other	46	0	46
Environmental	5	0	5

RESULTS

A total of 1445 MMs were identified. In 268 of these cases, the exposure information could be correlated with the result of tissue fiber burden analysis. These included 1322 men and 123 women. In some occupational categories, all were men. These included insulators, railroad workers, power plant workers, steel workers, automotive workers, boilerworkers, electricians and machinists. A large percentage of women with MM were household contacts. The building occupant category included about an equal number of men and women. The median age was similar across all occupations and industrial exposures, with the median age occurring in the seventh or eighth decade for most categories. Insulators were slightly younger, with a median age of 59.5 yr. Household contacts also had a median age of 59 yr, which reflects a mixture of individuals first exposed as adults (with median ages in the seventh or eighth decade) and those first exposed as children (mostly daughters of asbestos workers, with a median age in the fourth decade). Building occupants were also relatively young (47 yr), since many of these involved exposures allegedly beginning during childhood while attending school.

Two categories have often been considered as low-level exposures. These include household contacts of asbestos workers and environmental (neighborhood) exposures. There were 89 household contacts of an asbestos worker, 10 of which had additional occupational exposure to asbestos. Seventy-nine percent were women with an average age of 59 yr. There were four cases with environmental exposure to asbestos. All were men with an average age of 67 yr. None had any additional known exposure to asbestos. Three of these four cases were from a region of Turkey where there was intense environmental exposure to tremolite–actinolite. When these two categories, along with two fairly non-specific categories of 'other asbestos' and 'other' were excluded, the remaining 19 groups accounted for >94% of the 1445 MMs included in this study.

Approximately 90% of our cases arose in the pleura. The other 10% arose in the peritoneum. The highest percentage of peritoneal MM occurred among insulators and asbestos manufacturing plant workers. In each of these groups, the ratio of pleural to peritoneal tumors was about 2:1. In the remaining groups, this ratio ranged from 8.6:1 in construction workers to more than 50:1 in shipyard workers. The low ratio of 1.8:1 in building occupants indicates that peritoneal MMs in this setting are unlikely to be related to asbestos exposure. These observations also call into question the association of peritoneal MMs in women with low-dose asbestos exposure. Studies have shown that most peritoneal MMs in women are not associated with any prior history of asbestos exposure (Goldblum and Hart, 1995).

When information was available regarding the presence or absence of plaques (PPP), a high percentage of cases had plaques. Among occupationally exposed individuals, the percentage of patients with MM and plaques ranged from 50% in glass and ceramic workers to as high as 100% of papermill workers. Lower percentages were seen for non-occupational exposures, although PPP were present in nearly 60% of household contacts of asbestos workers.

When information was available regarding the presence or absence of asbestosis, a relatively low percentage of cases had histologically confirmed asbestosis. Among occupationally exposed individuals, the percentage of cases with asbestosis ranged from 0% of glass and ceramic workers and friction product workers to as high as 67% of asbestos manufacturing plant workers. Asbestosis was rarely observed among patients with MM and non-occupational exposure. None of the environmental exposures or building occupants had asbestosis, but asbestosis was confirmed histologically in 8.3% of household contacts of asbestos workers.

The median asbestos body count in each of the 23 exposure categories exceeded our normal range of 0–20 AB/g, except for two categories: automotive workers and building occupants. The industry with the highest median asbestos body count was the insulation industry, while the occupation with the highest count was boilermaker. Commercial amphiboles (mostly amosite with some crocidolite) were the predominant fiber type identified in each of the categories, except for four categories: automotive workers, household contacts, building occupants and environmental (neighborhood) exposures. In these instances, non-commercial amphiboles (mostly tremolite with some actinolite and anthophyllite) predominated over commercial amphibole fibers. Chrysotile fibers were detected less frequently, and were not detected in seven categories. Non-asbestos mineral fibers were present in all categories in roughly similar amounts.

Further analyses were performed on the 12 exposure categories for which there were 10 or more analyses within the category. Commercial amphibole fibers were present in concentrations that exceeded the background level in all 12 categories, ranging from 57% (other) to 100% (insulators) of the individuals in any one category. Non-commercial amphibole fibers were also present in excess concentrations in all 12 categories, ranging from 13% (maintenance workers) to 68% (shipyard workers) of individuals in any particular category. However, the percentage of individuals in a category with elevated levels of non-commercial amphiboles exceeded 50% in only two categories: shipyard workers and electricians. Chrysotile was present in excess concentrations in nine of the 12 categories (excluding in pipefitters, construction workers, or other), ranging from 5 to 23% of the individuals in any one category. In none of the categories was chrysotile found in elevated concentrations in more than half of the individuals in that category.

DISCUSSION

Two of the categories deserve comment. Household contacts of asbestos workers had tissue asbestos burdens that were similar to the median value for some occupational groups. For example, the median asbestos body count of household contacts (130 AB/g) was of the same order of magnitude as construction workers (190 AB/g), US Navy employees (170 AB/g) and machinists (100 AB/g). Hence, household contacts have tissue asbestos burdens that are, on average, equivalent to a mild to moderate occupational exposure (Gibbs *et al.*, 1990; Roggli *et al.*, 1998). Wives tended to have higher lung asbestos burdens than daughters or sons. In contrast, the median asbestos body count for automotive brake repair workers was within our normal range. In many of these cases, the tissue asbestos content was within the limits of background. In those cases with elevated tissue asbestos content, excess commercial amphibole fibers (mostly amosite) were invariably detected. These observations confirm our prior impression that friction product exposure, such as that encountered by automotive mechanics, is unlikely to contribute to the development of MM (Roggli *et al.*, 1992; Woitowitz and Rodelsperger, 1994).

It could be argued that these cases are not representative of the types of exposures occurring in MMs in the USA, since >90% are medicolegal cases. Therefore, we compared our data with that obtained by the Australian Mesothelioma Surveillance Program, which is a survey of all MMs in Australia. Such cases must be reported to the registry as proscribed by law. With the exception of MMs related to working in the Wittenoom mine in Australia, the major categories of exposure are remarkably similar to those noted in our series of cases.

CONCLUSIONS

This study shows that the vast majority of MMs occurring in the USA today can be placed into a limited number of exposure categories, which include 12 industries and six occupations with known asbestos exposure. Household contacts of asbestos workers accounted for most of the remainder of the cases, with neighborhood exposures rarely contributing to MM. Overlap of categories was common, with individual workers often having exposures in more than one category. Commercial amphiboles were found in excess amounts in all 19 categories. Non-commercial amphiboles were found in excess amounts in a smaller percentage of cases, while cases in which the level of chrysotile exceeded background were infrequent.

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