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Mesothelioma and Employment in Massachusetts: Analysis of Cancer Registry Data 1988–2003

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Background *Cancer registries can be used to monitor mesothelioma cases and to identify occupations and industries previously and newly associated with mesothelioma-causing asbestos exposure by using standard registry data on the "usual" occupation and industry of the case.*

Methods *We used the National Institute for Occupational Safety and Health's Standardized Occupational Industry Coding Software to code 564 mesothelioma cases for occupation and 543 for industry of the 1,424 incident mesothelioma in the Massachusetts Cancer Registry from 1988 to 2003. Additionally, we coded the occupation and industry of 80,184 comparison cancer cases (35% of comparison cases in our database). These were used to compute Standardized Morbidity Odds Ratios (SMORs).*

Results *Seventeen occupations and 11 industries had statistically significant elevated SMORs for mesothelioma. Occupations and industries historically associated with mesothelioma remained elevated in these results. However, we also found statistically significant elevated SMORs for several occupations and industries for which there was previously weak or no association such as chemical engineers, machine operators, and automobile mechanics and machine manufacturing, railroads, and the U.S Postal Service.*

Conclusions *Incident cases of mesothelioma do not appear to be declining in Massachusetts, as legacy exposures to asbestos continue to produce cases in individuals involved in shipbuilding and construction. Exposures in occupations and industries not previously associated with mesothelioma also contribute cases. Cancer registries, with improved data collection, should continue to be monitored for mesothelioma cases and asbestos exposures.* Am. J. Ind. Med. © *2013 Wiley Periodicals, Inc.*

KEY WORDS: mesothelioma; asbestos exposure; surveillance system; occupations; industries; cancer

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INTRODUCTION

Mesothelioma is a rare and highly fatal cancer of the chest or abdominal lining caused by exposure to asbestos fibers [Selikoff et al., 1964]. Investigations of mesothelioma cases generally record experience of asbestos exposure in the workplace, although environmental exposure, exposure to products and exposure to "take-home" asbestos have also been documented [Albin et al., 1999; Miller, 2005; Rake et al., 2009; Carbone et al., 2011]. Public health surveillance of mesothelioma can reveal the burden of occupational and environmental disease in the population, evaluate the impact of prevention efforts over time, and identify previously unrecognized settings in which workers and community members may continue to be at risk of asbestos exposure [Hillerdal, 1999; Mirabelli et al., 2010]. About 97 cases of mesothelioma have been reported to the Massachusetts Cancer Registry (MCR) annually since 2000. The age-adjusted incidence rate of mesothelioma in Massachusetts for 2007 was 17.9 per million residents, 1.4 times the estimated national rate 12.6 [Occupational Health Surveillance Program, Massachusetts Department of Public Health, April 2011]. The age-adjusted death rate for mesothelioma in Massachusetts between 1999 and 2005 was 14.8/million residents placing Massachusetts at the tenth highest mesothelioma death rate in the U.S. [U.S. National Institute for Occupational Safety and Health, March 2009] Massachusetts' long history of shipbuilding, an industry where many thousands of workers were exposed to asbestos, plays a significant part in explaining this higher than average rate. Recent analyses of national data predicted that mesothelioma incidence would peak in the United States in between 2005 and 2010 and decline sharply thereafter [Price and Ware, 2009]. However, it is not clear that a peak has occurred in Massachusetts (see Fig. 1).

Despite the dramatic decline in the use of asbestos and increases in worker and environmental regulatory protections, individuals continue to be exposed to asbestos at work and in other settings [U.S. National Institute for Occupational Safety and Health, 2011]. In particular, an evolving category of exposure—exposure to in-place asbestos in buildings—may result in mesothelioma cases in maintenance and abatement workers (as well as building occupants). In 2009, there were 165 licensed asbestos contractors in Massachusetts. These companies employ hundreds of workers, many of whom are new immigrants. While these workers may be protected by Occupational Safety and Health Administration's (OSHA) strict asbestos standard and additional Massachusetts' regulations, annual reports of enforcement actions against illegal asbestos removal suggest that exposure may occur despite the new regulatory environment.

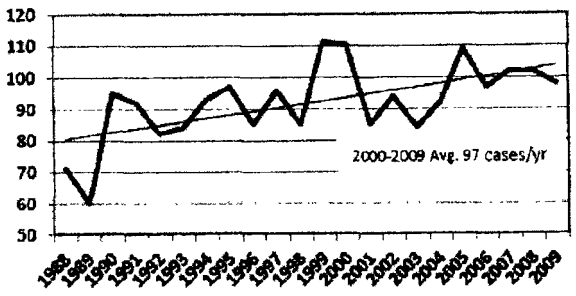

FIGURE 1. Mesothelioma incident cases diagnosed in Massachusetts (1988–2009)

In this context, we initiated a surveillance investigation to examine mesothelioma incidence using data reported to the MCR 1988–2003, updating a prior report based on similar methods for the years 1983–1987 [Occupational Health Surveillance Program, Massachusetts Department of Public Health, 1991]. The goal of the study, funded by the International Mesothelioma Program of the Division of Thoracic Surgery at the Brigham and Women's Hospital, was to examine the association between mesothelioma incidence and usual industry and occupation and to identify changes in patterns over time by comparing results with those of the previous study

MATERIALS AND METHODS

The MCR was established in 1982 to collect information on the incidence of malignant neoplasms in the state. All hospitals or organizations holding a clinic license in Massachusetts are required to report newly diagnosed cancer cases to MCR within 6 months of initial diagnosis. (Physicians' offices and pathology laboratories began reporting in 2001; radiation therapy centers in 2002.) Case reports contain diagnostic and demographic information, including the case's description of their usual occupation and industry. International Classification of Diseases for Oncology (ICD-O) codes for primary cancer site and histology in the MCR are assigned by tumor registrars at the reporting hospitals (http://www.who.int/classifications/icd/adaptations/oncology/en/index.html).

Following a research protocol and data request review by the University of Massachusetts Lowell Institutional Review Board and the Massachusetts Department of Public Health Human Research Review Committee, de-identified mesothelioma and comparison cancer cases among Massachusetts residents diagnosed in 1988 through 2003 and reported to the MCR were obtained for the analysis.

Mesothelioma cases were defined by ICD-9 histology codes 9050–9053. Comparison cancer cases included cases with cancers that have not been associated with asbestos fibers: penis and scrotum, prostate gland, testis, bone and joints, connective and soft tissue, vagina and labia, vulva,

cervix uteri, corpus uteri, other female genitalia, breast, melanoma, leukemia, and lymphoma. All other cancers, including lung cancer, were excluded.

Usual industry and occupation information reported to the MCR is not routinely coded. Industry and occupation codes were assigned using Standardized Occupational Industry Coding Software (SOIC) developed by the U.S. National Institute for Occupational Safety and Health (http://www.cdc.gov/niosh/soic/SOIC_About.html). SOIC uses codes from the 1990 U.S. Bureau of the Census Alphabetical Index of Industries and Occupations.

Data were cleaned prior to the application of SOIC to make text uniform in order to maximize assignment of codes and minimize coding errors. MCR narrative fields could vary for the same occupation. For example, a case with usual occupation "carpenter" who was retired at the time of diagnosis could be described as "ret. Carpenter," "carpenter-retired," retired carpenter," "retired," "carpenter," "at home carpenter," etc. Thus, we "cleaned" the text to read only "carpenter" to be coded by SOIC. Initial frequency analysis of SOIC assigned codes indicated that multi-word occupation and industry strings were often assigned codes "900" and above indicating "unknown," or "unspecified." Many "current homemakers" or "disabled" had had previous jobs that were recorded as the second word in the narrative. As a result, these jobs were not initially coded by SOIC. We modified the descriptions in order to assign codes based on these second words for all multi-word strings initially coded greater than 900. Applying this strategy to codes less than 900 was not feasible, as it would have required a manual review of all cases.

ANALYSIS

Because only numerator data were available for this study, we used Standardized Morbidity Odds Ratios (SMORs) to measure the association between mesothelioma and specific occupations and industry [Miettinen and Wang, 1981; Smith and Kliewer, 1995]. The SMOR compares the ratio of mesothelioma to other cancers in the occupation or industry of interest (exposed group) cases with other known occupations or industries (unexposed group). The SMOR for a given occupation or industry can also be thought of as the ratio of the observed number of cases in that group divided by the number expected, where the expected is based on the ratio of mesothelioma cases to comparison cancer cases in those employed in other industries and occupations. Cases employed in the shipbuilding or construction industries, or in 32 construction occupations that are known to have asbestos exposure, for example, plumbers, insulation workers, carpenters, were excluded from the unexposed industry and occupation groups. Cases with unknown occupation or industry were excluded from the analysis as it was not possible to determine the exposure status. A SMOR greater than one indicates increased risk of mesothelioma cancer in the industry/occupational group compared to the exposed reference group.

Logistic regression was used to compute SMORs and 95% Wald Confidence Limits for each industry and occupation group with five or more observed cases of mesothelioma, controlling for gender and age. An SMOR was also computed for homemakers. Age was examined in three distribution-based groups in the final model: 20–54 year of age, 55–69 years of age, and 70 and above. We tested 10- and 20-year intervals initially in order to control adequately for age differences between cases and the comparison cancers group. The stability of confidence interval was the same, and in light of mesothelioma's long latency, we used a parsimonious approach. Cases younger than 18 years old ($n = 2$) were excluded from the analyses. Analyses were performed using SAS v. 9.1.

RESULTS

There were 1,424 cases of mesothelioma in the MCR 1988–2003 Table I shows the demographic distribution of the mesothelioma cases. This distribution is similar to the distribution seen in the previous study, except that the current results include more younger cases: 19 cases younger than 40 The majority of the cases were from counties and towns with a history of shipbuilding industries. We were able to code 564 mesothelioma cases (40%) for occupation (excluding retired, unknown and disabled) and 543 (38%) for industry. The majority of the cases (and the comparison group) were reported as retired, unknown or disabled and were excluded. The comparison group consisted of 80,184 cancer cases coded for occupation and industry (35% of the total comparison cases). As shown in Table II, 17 occupations had statistically significant elevated SMORs for mesothelioma. Most of these occupations historically have been associated with asbestos exposure and mesothelioma,

TABLE I. Characteristics of Mesothelioma Cases in the Massachusetts Cancer Registry 1988–2003

	n	%
Total cases	1,424	
Male	1,166	82
White	1,371	96
Age 59 or younger	221	16
Age 60 or older	1,202	84
Occupation coded	1,258	88
Occupation coded excluding unknown, disabled, retired	564	40
Industry coded	1,324	93
Industry coded excluding unknown, disabled, retired	543	38

TABLE II. Occupations With 5 or More Mesothelioma Cases, Massachusetts Cancer Registry, 1988–2003

Occupation	Code	Number of Cases	SMOR	95 % CI
Insulation workers	593	9	**38.4**	17.7–83.5
Boiler makers	643	5	**22.6**	8.5–60.5
Plumbers, pipefitters, and steamfitters	585	49	**9.5**	7.0–12.8
Welders and cutters	783	22	**10.1**	6.5–15.8
Chemical engineers	48	5	**5.3**	2.1–13.1
Electricians	575	31	**5.1**	3.5–7.4
Brickmasons and stonemasons	563	9	**4.6**	2 4–9 0
Stationary engineers	579	7	1.6	0.8–3.5
Machine operators, not specified	779	12	**3.5**	2.0–6.3
Drafting occupations	217	5	**3.0**	1.2–7.2
Sheet metal workers	653	7	**3.5**	1.6–7.4
Construction laborers	869	23	**2.9**	1 9–4.4
Production inspectors, checkers, and examiners	796	7	**2.9**	1.4–6.1
Military occupations	905	12	**2.3**	1.3–4 1
Firefighting occupations	417	19	**2.2**	1.4–3.4
Automobile mechanics	505	10	**2.1**	1.1–4.0
Carpenters	567	25	**2.2**	1 5–3 3
Technicians, n.e c.	235	9	1.8	0.9–3.5
Designers	185	5	1.8	0.7–4.3
Cooks	436	6	1.7	0.8–3.9
Machinists	637	20	**1.8**	1.2–2.9
Secretaries	313	14	1.7	1.0–2.8
Painters, construction, and maintenance	579	7	1.6	0.8–3.5
Mail carriers	355	5	1.5	0.6–3.7
Janitors and cleaners	453	23	1.4	0.9–2.1
Miscellaneous machine operators	777	7	1.5	0.7–3.2
Social workers	174	5	1.7	0.7–4.0
Postal clerk	354	7	1.3	0.6–2.7
Bookkeepers, accounting, auditing clerks	337	5	1.4	0.6–3.5
Electric and electronic engineers	55	7	1.0	0.5–2.0
Homemakers	914	35	1.1	0.8–1.6
Police and detectives	418	9	0.9	0.4–1.8
Construction supervisors, n.e.c.	558	6	1.1	0.5–2.6
Sales supervisors, sales occupations	243	17	1.0	0.6–1.6
Truck drivers	804	14	0.9	0.5–1.7
Managers and administrators n.e.c.	22	21	0.7	0.5–1.1
Teachers, elementary school	156	19	0.9	0.5–1.4
Laborers except construction	889	8	0 9	0.5–1.8
Lawyers	178	8	0 7	0.4–1.4
Sales workers	274	12	0.7	0.4–1.3
Accountants and auditors	23	8	0.7	0.4–1.4
Registered nurses	95	6	0 7	0.3–1.6
Funeral directors	19	9	0.7	0.4–1.3
Engineers, n.e.c.	59	10	0.7	0.4–1.4
General office clerks	379	5	0 6	0.2–1.4

Confidence intervals were rounded to the nearest digit Statistically significant SMORs are bolded.

however, some, including chemical engineers, brickmasons, machine operators, drafting occupations, production inspectors, military occupations, firefighting occupations, and automobile mechanics, are less commonly identified as having elevated rates of mesothelioma in comparisons to other occupational groups. Several other occupations had elevated SMORs that approached statistical significance, including technicians not otherwise classified, stationary engineers, painters, secretaries, and janitors and cleaners.

The ship and boat building and repairing and construction industries contributed the largest numbers of cases (96 and 127, respectively) among the 11 industries with statistically significant elevated SMORs, but other industries such as justice, public order and safety also contributed a large number of cases (Table III). Ship and boat building and repair had the highest SMOR by far (38.2) with the next highest at 7.3 for miscellaneous repair services. (According to the Standard Industrial Classification system, "miscellaneous repair services" includes several diverse repair activities including of air conditioning machinery, farm machinery, clocks, furniture, lawn mowers and sewers.) Water transportation, construction, and the military also had highly elevated SMORs. Apparel, footwear manufacturing, and motor vehicle dealers showed SMORs that were notably elevated, although their SMORs were non-statistically significant.

DISCUSSION

Public health surveillance using data collected in disease registries can monitor patterns of disease in certain populations known to be at risk, and can generate new hypotheses about populations potentially exposed to disease risk factors [Kang et al., 2008]. This study confirms that occupations and industries historically associated with asbestos exposure continue to be sources of cases of mesothelioma at elevated levels. The long latency period of this disease means that historic exposures are still producing cases of this deadly disease. Additionally, despite increased regulation, compliance and awareness, asbestos exposures may have continued in the asbestos-using and removing industries. Little is known about the disease potential of occupational and environmental exposures to in-place asbestos in buildings and other settings. Our results point to specific industries and occupations where exposures should be characterized.

Our study analyzed data from the MCR from the years 1988 to 2003. Because we used a similar analysis strategy to that employed in a previous study for the years 1982–1987, we were able to compare the SMORs of occupations and industries in these two time periods. Occupations with statistically significant elevated risk in both studies included: insulation workers, boilermakers, plumbers, pipe and steamfitters, construction workers, carpenters, and engineers (may include chemical). The construction and ship and boat building industry sectors were also at elevated risk at a statistically significant level in both studies. A few differences between these two studies warrant attention. We were able to find a greater number of occupations and industries with statistically significant elevated risk in the second study due to the greater number of cases in the dataset and greater specificity of occupational coding. Many of the occupations that newly appeared elevated at a statistically significant level: chemical engineers, brick and stonemasons, drafting occupations, machine operators, automobile mechanics and military occupations, may have been included in broader occupational categories, such as "engineers," "construction laborers," and "mechanics and repairers" which were elevated in the earlier study Industries that showed statistically significant elevated risk in the later study, but not the earlier one were railroads, U.S Postal Service, machine manufacturing, and the military.

Analysis of publically available cancer incidence and mortality data poses both advantages and limitations for understanding the patterns of mesothelioma [Levy et al., 2001]. The large number of cases in the MCR allowed us to find a relatively great number of SMORs for occupations and industries that were statistically significant based on 95% confidence level. However, in some instances, SMORs were computed based on small number of cases resulting in wide confidence intervals. Additionally, while demographic information is thought to be highly reliable for these cases, the occupation and industry categories are more problematic. Less than 40% of the mesothelioma cases and comparison cancers had sufficient information in the MCR occupation and industry narrative fields to allow coding. Additionally, we conducted a validation study on a subset of cases to compare manual and SOIC coding and found that SOIC correctly coded about 70% of the occupations and industries, leaving about 30% of information vulnerable to exposure misclassification. However, this misclassification would likely be non-differential, i.e., to the same degree in cases and the comparison group, and hence, bias the results towards the null. Due to the size of the database it was not feasible to manually code the occupations and industries, however, we used SAS to identify cases where we could improve the uniformity of the text narrative and thereby improve the completeness and specificity of SOIC coding. This strategy minimized observer (coder) bias since the same, consistent approach was used to assign appropriate industrial/occupational codes to all cancer cases. Little bias is likely to have been introduced from these data limitations, however, since there is no reason to believe they would be more or less likely to occur for mesothelioma versus comparison cancer cases. Additionally, we were not able to compare the comparison cancer cases to Massachusetts population data over the time period of the study to determine if this large group is representative of the Massachusetts population as a whole.

TABLE III. Industry Groups and Subgroups With Five or More Reported Mesothelioma Cases, Massachusetts Cancer Registry, 1988–2003

	Code	Number of cases	SMOR	95% CI
Construction	060	**127**	**3.2**	2.6–3.9
Manufacturing		**149**		
Yarn, thread, and fabric mills	142	5	1.1	0.4–3.3
Apparel and accessories, except knit	151	6	2.7	1.0–7.3
Pulp, paper, and paperboard mills	160	5	**2.9**	1.2–7.1
Printing, publishing, and allied industries, except newspaper	172	5	0.8	0.2–2.4
Footwear, except rubber and plastic	221	5	2.5	0.8–2.8
Machine, except electrical, n.e.c.	331	9	**2.7**	1.3–5.5
Ship and boat building and repairing	360	96	**38.2**	29.4–49.7
Not specified	392	18	1.4	0.9–2.4
Transportation		**39**		
Railroads	400	7	**3.2**	1.4–7.3
Trucking service	410	7	0.7	0.3–1.6
U.S. Postal Service	412	19	**1.7**	1.1–2.7
Water transportation	420	6	**3.4**	1.5–7.7
Communication		10		
Telephone communication	441	10	1.2	0.6–2.5
Utilities and sanitary services		**8**		
Electric light and power	450	8	1.5	0.6–4.1
Retail trade		**14**		
Motor vehicle dealers	612	7	2.1	**1.0–4.5**
Eating and drinking places	641	7	0.8	**0.4–1.6**
Finance, insurance, and real estate		**14**		
Banking	700	6	0.9	0.4–2.1
Real estate, including real-estate insurance offices	712	8	1.0	0.5–2.0
Business and repair services		**27**		
Business services, n.e.c.	741	6	1.4	0.6–3.1
Automotive repair and related services	751	11	**2.2**	1.2–3.9
Miscellaneous repair services	760	10	**7.3**	3.8–13.9
Professional and related services		**95**		
Hospitals	831	15	0.9	0.5–1.7
Health services, n.e.c.	840	7	0.8	0.4–1.7
Legal services	841	9	1.0	0.5–2.0
Elementary and secondary schools	842	31	0.9	0.6–1.3
Colleges and universities	850	11	0.6	0.3–1.1
Engineering architectural and surveying services	882	17	1.3	0.8–2.1
Accounting, auditing, and bookkeeping services	890	5	1.6	0.7–3.9
Public administration		**70**		
General government, n.e.c.	901	16	0.8	0.4–1.4
Justice, public order, and safety	910	33	**1.5**	1.1–2.2
National security and international affairs	932	8	1.8	0.7–4.3
Military	942	17	**3.3**	1.8–6.1

Confidence intervals were rounded to the nearest digit. Statistically significant SMORs are bolded

The major limitation of a cancer registry-based surveillance strategy is that recorded usual industry and occupation is a limited surrogate for a detailed exposure history. Reported usual occupation and industry may miss or mask the true source of the asbestos exposures, or may suggest universal exposure for non-uniform occupations. For example, our study found an elevated SMOR for the U.S. Postal Service Postal workers may have had exposure to asbestos at work,

but it is also possible that U.S. Postal Service hiring may favor veterans, many of whom may have had asbestos exposure through their military service. Additionally, we found elevated SMORs for automobile mechanics and janitors and cleaners (non-statistically significant). In both cases, and unlike insulation work, these occupations include a wide variety of tasks and job settings, only some of which may involve exposure to asbestos. Some automobile mechanics may be exposed to asbestos when cleaning worn asbestos-containing vehicle brakes. Janitors and cleaners may also face exposure to "in-place" asbestos put into buildings by the historically at-risk construction industry. While not all automobile mechanics or janitors and cleaners are exposed to asbestos on the job, our findings support the continue monitoring of these occupations and efforts to prevent exposure to asbestos from "in-place" asbestos and asbestos products. Despite the limitations of this "surrogate" exposure monitoring for a long-latency disease, the large number of cases reported to the Registry allows us to describe trends and to find suspect occupations and industries that may warrant further investigation of potential disease-causing exposures.

CONCLUSIONS AND RECOMMENDATIONS

Many results of the study are consistent with previous investigations of the association of particular occupations and industries with mesothelioma. Industries and occupations with historical asbestos exposure, such as insulation workers, and those who worked in ship and boat building and construction, have continued to be at risk of developing disease. There are number of occupations such as drafting occupations and occupations related to U.S. Postal Service, such as mail carriers or postal clerks that were not previously reported to be at risk for mesothelioma. It is not possible in this analysis to determine if these cases resulted from exposure to asbestos experienced during employment in the reported "usual" occupation, i.e., work in a post office, or if these cases were exposed to asbestos in a prior occupation such as ship building, or in the military, or in another occupation or exposure context not reported as their "usual occupation." However, there should be further surveillance and investigation of potential asbestos exposure for all occupations and industries with elevated SMORs for which there has not been a previously demonstrated risk or characterized exposure.

The limited number of code-able occupation and industry fields points to a recommendation for improvement in data collection. In many cases, the fields were blank and in many others hospital registrars recorded "retired," "disabled," or "unemployed." Comparison of cancer registry data to death certificates may help improve data capture and accuracy [Davis et al., 1992]. Hence, electronic data linkage should be considered as a routine strategy in cancer registry-based surveillance.

Despite the usual long latency between exposure and disease, a continuing program of mesothelioma surveillance is recommended to monitor the progress of exposure control and prevention and to identify suspect exposures [Teschke et al., 1997]. Even with the increasing federal and state regulation of asbestos exposure through the last decades of the twentieth century, and even most recently with OSHA's National Emphasis Program on Shipbreaking issued in 2010, some workers, such as those performing asbestos abatement activities or those with exposure to "in-place" asbestos in buildings and products may be at risk of the disease. Improved medical record keeping and reporting could help support an effective public health surveillance system for asbestos-related diseases and other diseases related to occupational exposures.

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