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A Case-Control Study of Multiple Myeloma and Occupation

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Lifetime job histories from a population-based, case-control study were analyzed to investigate the relationship between multiple myeloma and employment in various occupations and industries. Interviews were obtained from 89% (692) of eligible incident cases and 83% (1683) of eligible controls. An elevated risk was observed among persons ever employed as painters [odds ratio (OR) = 2.1, 95% confidence interval (CI) = 1.2–3.6], particularly for those employed for 10 or more years (OR = 4.1, 95% CI = 1.8–10.4). A small excess risk was observed among agricultural workers employed for 10 or more years (OR = 1.3, 95% CI = 1.0–2.2). with a higher relative risk observed among farm laborers (OR = 1.8, 95% CI = 1.0–4.0). Among agricultural workers who reported having been highly exposed to pesticides, the OR was 5.2 (95% CI = 1.6–21.1). Some evidence, based on smaller numbers, was also found to support an association with firefighting and employment in the petroleum- and coal-products manufacturing industries. Little evidence was found to support the previously noted association with wood exposure, and no evidence for an association with employment in the rubber or petroleum refining industries was found. This study lends further support to previously reported associations between multiple myeloma and employment among painters and agricultural workers.

Key words: occupational diseases, painters, agricultural workers, multiple myeloma

INTRODUCTION

A number of epidemiologic studies have examined the association between multiple myeloma and employment in particular occupations or industries. The strongest evidence has linked employment in agriculture with an increased risk of multiple myeloma [Boffetta et al., 1989; Burmeister et al., 1983; Cantor and Blair, 1984; Cuzick and De Stavola, 1988; Flodin et al., 1987; Gallagher et al., 1983; La Vecchia

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et al., 1989; Milham, 1971; Pearce et al., 1986; Steineck and Wiklund, 19861. Elevated relative risks also have been observed for employment in occupations involving working with wood [Flodin et al., 1987; Milham and Demers, 1984; Milham, 1976; Nandakumar et al., 1986; Tollerud et al., 1985], painting or paint manufacturing [Adelstein, 1972; Berthwaite et al., 1990; Cuzick and De Stavola, 1988; Friedman, 1986; Lundberg, 19861, and exposure to radiation [Cuzick, 1981; Gilbert et al., 1989]. Associations between multiple myeloma and employment in the oil and petrochemical industry [Wong and Raabe, 1989], in rubber manufacturing [Riedel et al., 1991], and as a firefighter [Howe and Burch, 1990] also have been reported. However, results have been inconsistent across studies, and considerable uncertainty remains concerning the role of occupation in the etiology of multiple myeloma [Riedel et al., 1991].

In this paper, analyses of lifetime work histories from participants in a large, population-based, case-control study are presented. In an earlier analysis from this study, the relationship between multiple myeloma and self-reported occupational and nonoccupational exposure to a broad range of chemicals and potentially toxic substances was examined [Moms et al., 19861. The goal of the current study was to examine systematically the association between multiple myeloma and employment in various occupations or industries.

MATERIALS AND METHODS

Data on cases and controls were collected as part of a collaborative study of risk factors for multiple myeloma and chronic lymphocytic leukemia [Koepsell et al., 19871. Cases were identified through tumor registries in four geographic areas: King and Pierce counties in Washington state; Davis, Salt Lake, Utah, and Weber counties in Utah; five counties of metropolitan Atlanta; and the three metropolitan Detroit counties. The four tumor registries are participants in the Surveillance, Epidemiology, and End Results program of the National Cancer Institute. All residents under the age of 80 years who were newly diagnosed with multiple myeloma between July 1, 1977, and June 30, 1981, were approached through their physicians for participation in the study.

Controls were selected to be similar in age and sex to the cases but otherwise were representative of the population in the regions. In Washington state, the two-county region was divided into 175 areas of approximately equal population, within which two sampling units of approximately four households each were selected. All residents between the age of 65 and 79 years, and one out of nine residents between the age of 40 and ***64*** years were approached for participation. In the three other geographic study areas, random digit dialing methods were used. Control selection methods are more fully described elsewhere [Koepsell et al.. 1987].

Cases, or their survivors, and controls were queried by trained interviewers on a broad range of risk factors. Interviews were obtained for 692 (89%) of the 773 eligible cases and 1,683 (83%) of the 2,024 eligible controls. Four hundred seventy-two (68%) cases were interviewed directly. while the remainder of interviews were conducted with a proxy respondent. Lifetime work histories were collected, and occupations and industries were coded according to the 1970 U.S. Census codes.

Stratified analysis of occupational histories was performed using a computer program developed by one of the authors [Vaughan. 1989}. Mantel-Haenszel odds

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ratios were calculated for ever having been employed in particular occupations or industries after adjustment for sex, age (<50, 50–59. 60–69, 70–79 years), race (white, black, other), and study area. To evaluate the use of surrogate respondents as a potential source of bias, the analyses were repeated with the self-respondent subjects only. Cornfield 95% confidence intervals (CI) were calculated except in cases when there were fewer than five exposed cases or controls, in which case exact methods were used [Breslow and Day, 1980].

RESULTS

The demographic characteristics of the study population have been presented elsewhere [Koepsell et al., 19871. Odds ratios and 95% CI for ever having been employed in specific occupational groups are presented in Table I. In analyses using all respondents, elevated odds ratios were observed among painters [odds ratio (OR)=2.1, 95% CI=1.2–3.5], those employed in forestry and logging occupations (OR=2.5, 95% CI=1.1–12), and metal and plastic working machine operators (OR=1.7. 95% CI=1.1–2.5). Elevated risks also were observed for many other occupations including mathematical and computer scientist, "other" health treatment occupations, firefighters, and insulation workers, although the confidence intervals were quite broad. Decreased risks were observed for engineers, architects, and surveyors (OR=0.3, 95% CI=0.2–0.9), engineering and science technicians (OR=0.4, 95% CI=0.2–1.1), and rail and water transportation workers (0.3, 95% CI=0.1–1.1). Additional adjustment for education (as a surrogate measure of socioeconomic status) did not substantially alter the results. For example, only four of the 60 OR for all respondents in column 1 of Table I were altered by greater than **0.2,** and these were based on small numbers.

Controls and self-respondent cases both reported an average of **3.5** previous occupations whose mean durations were 9 years each, while case interviews obtained from surrogate respondents had an average of 2.7 previous occupations, with a mean duration of 11 years. This may suggest that surrogate respondents provided a relatively less detailed work history. However, restricting the analysis to self-respondent cases (Table I. column 2) did not substantially alter the conclusions drawn **on** the basis of all respondents.

Table II presents the results by industry group. When the analysis included all study participants, elevated risks were observed among persons ever employed in aircraft and aircraft parts manufacturing (OR=1.6, 95% CI=1.1–2.9) and forestry (OR=2.1, 95% CI=0.3–13.0), although the latter was based on small numbers. When the analysis was restricted to self-respondent cases, the risk among workers employed in agricultural (OR=1.6, 95% CI=1.2–2.6) and mining (OR=1.8, 95% CI=1.1–4.0) increased.

Table III presents analyses by duration of employment (< 10 years or ≥ 10 years) for occupational groups of a priori interest or whose confidence intervals excluded one in either the full or self-respondent analyses. Results are also presented for the more specific occupations within the grouped categories when the results were informative. The ORs for multiple myeloma among painters in both construction and manufacturing industries increased with duration of employment. The majority of the painters in manufacturing had been employed in the motor vehicle industry (nine cases and 13 controls). Evidence for a duration-response effect was also found among firefighters, farm laborers, farmers, miners, and metal- and plastic-working machine

TABLE I. Relative Risk of Multiple Myeloma by Occupational Group

Occupational group	All respondents			Self-responding cases only	
	Cases	Controls	OR (95% CI)[a]	Cases	OR (95% CI)[a]
Admin. and managerial occupations	109	309	0.8 (0.6–1.1)	77	0.9 (0.7–1.3)
Engineers, architects, surveyors	8	47	0.3 (0.2–0.9)	3	0.2 (0.0–0.8)
Mathematical and computer scientists	4	4	2.2 (0.4–13.2)	3	2.2 (0.3–14.9)
Natural scientists, except chemists	2	4	0.9 (0.1–8.1)	2	1.5 (0.1–13.0)
Chemists and chemical technicians	3	6	1.7 (0.3–8.3)	1	0.8 (0.0–7.3)
Health diagnosing occupations	2	8	0.6 (0.1–3.1)	2	0.8 (0.1–4.4)
Nurses (RNs and LPNs)	10	35	0.6 (0.3–1.4)	6	0.5 (0.2–1.6)
Other health treatment occupations	5	4	2.8 (0.6–15.4)	4	3.5 (0.5–22.9)
Educators. librarians. educ. counselors	29	106	0.6 (0.4–1.0)	23	0.8 (0.5–1.4)
Social, legal, recreational. religious	16	49	0.8 (0.5–1.8)	10	0.8 (0.4–1.9)
Writers, entertainers, athletes	14	39	0.8 (0.4–1.7)	8	0.8 (0.3–1.9)
photographers, painters. artists	3	7	1.0 (0.2–4.6)	3	1.5 (0.2–7.1)
Health technicians	4	10	1.1 (0.2–4.2)	4	1.8 (0.3–7.3)
Engineering, science technicians	6	47	0.4 (0.2–1.1)	4	0.4 (0.1–1.2)
Other technicians	6	25	0.5 (0.2–1.4)	4	0.5 (0.1–1.7)
Sales occupations	123	302	1.0 (0.8–1.4)	83	1.1 (0.9–1.6)
Administrative support occupations	175	449	1.0 (0.9–1.4)	114	1.1 (0.9–1.6)
Private household service occupations	56	122	1.0 (0.7–1.7)	34	1.0 (0.6–2.0)
Fire fighting and prevention occupations	5	5	1.9 (0.5–9.4)	4	2.8 (0.5–14.5)
Law enforcement and guards	20	54	1.1 (0.6–2.1)	11	1.0 (0.4–2.0)
Food service occupations	79	200	0.9 (0.7–1.3)	57	1.1 (0.9–1.8)
Health service occupations	25	57	1.1 (0.7–2.0)	20	1.5 (0.9–3.1)
Cleaning service, except household	68	154	1.0 (0.8–1.6)	43	1.1 (0.8–1.9)
Personal service occupations	27	70	0.8 (0.6–1.6)	19	0.9 (0.6–2.0)
Fanners	26	55	1.2 (0.8–2.5)	19	1.4 (0.9–3.3)
Farm workers and gardeners	57	138	1.0 (0.8–1.6)	42	1.3 (0.9–2.1)
Forestry and logging occupations	10	7	2.5 (1.1–12)	6	2.3 (0.9–15.4)
Vehicle mechanics	24	72	0.8 (0.5–1.4)	16	0.9 (0.5–1.6)
Industrial mechanics and maintenance	6	8	1.8 (0.5–6.7)	5	2.2 (0.6–8.5)
Electrical/electronic equip. repairers	5	13	0.7 (0.2–2.4)	2	0.4 (0.0–1.9)
Miscellaneous mechanics and repairers	22	68	0.8 (0.6–1.7)	13	0.8 (0.5–2.0)
Carpenters	17	36	1.0 (0.5–2.0)	13	1.3 (0.6–2.8)
Electricians	6	26	0.7 (0.2–1.8)	4	0.7 (0.2–2.3)
Painters	31	40	2.1 (1.2–3.6)	22	2.5 (1.3–4.7)
Plumbers. pipefitters, and steamfitters	6	13	1.0 (0.3–3.1)	5	1.3 (0.4–4.5)
Roofers and pavers	1	6	0.6 (0.0–5.0)	1	1.0 (0.0–8.9)
Insulation workers	7	0	Inf. (0.1–Inf)	2	Inf. (0.1–Inf)
Other construction occupations	10	29	1.0 (0.5–2.3)	7	1.2 (0.5–3.1)
Mining occupations	18	36	1.5 (0.9–3.3)	14	1.8 (1.1–4.9)
Supervisors. production occupations	18	44	1.1 (0.7–2.4)	12	1.2 (0.6–2.9)
Recision metal workers	27	83	0.8 (0.5–1.3)	20	0.9 (0.5–1.7)
Precision wood workers	2	2	1.9 (0.1–28.8)	1	2.1 (0.0–46.1)
Precision textile workers	12	27	1.0 (0.5–2.2)	7	0.9 (0.3–2.3)
Recision workers. assorted materials	3	4	1.8 (0.2–12.3)	3	2.9 (0.4–20.5)
Recision food production occupations	15	32	1.3 (0.6–2.6)	12	1.8 (0.8–4.1)
Inspectors, testers, and calibrators	25	94	0.7 (0.5–1.2)	19	0.9 (0.6–1.7)
Plant and system operators	1	3	0.5 (0.0–6.8)	1	0.8 (0.0–12.0)
Metal- and plastic-working machine operators	42	84	1.6 (1.1–2.5)	27	1.9 (1.1–3.1)
Metal- and plastic-processing machine operators	6	13	1.2 (0.4–3.6)	3	1.1 (0.2–4.6)
Woodworking machine operator	0	3	0.0 (0.0–2.6)	0	0.0 (0.0–3.6)
Printing machine operators	4	17	0.6 (0.1–2.0)	2	0.5 (0.1–2.4)
Textile machine operators	33	89	0.8 (0.5–1.3)	23	0.9 (0.5–1.5)
Other machine operators	92	296	0.8 (0.6–1.1)	63	1.0 (0.7–1.4)
Welders and cutters	22	53	1.2 (0.7–2.0)	14	1.3 (0.6–2.6)
Other hand working occupations	45	140	0.9 (0.6–1.3)	26	0.9 (0.6–1.5)
Motor vehicle operators	76	186	1.2 (0.8–1.6)	56	1.5 (1.0–2.2)
Rail and water transportation workers	4	23	0.3 (0.1–1.1)	2	0.2 (0.0–1.1)
Material moving equipment operators	19	37	1.5 (0.8–2.9)	12	1.6 (0.8–3.4)
Handlers, cleaners. and laborers	143	328	1.0 (0.9–1.5)	94	1.1 (0.9–1.7)
Garage and service station occupations	13	45	0.8 (0.4–1.5)	9	0.8 (0.3–1.7)

'Odds ratio (OR) adjusted for sex, race. age. and study area and 95% confidence intervals (CI).

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Industry group	All respondents Cases	Controls	OR (95% CI)[a]	Self-responding cases only Cases	OR (95% CI)[a]
Agriculture	84	181	1.2 (1.0–1.9)	62	1.6 (1.2–2.6)
Forestry	4	4	2.1 (0.3–13.0)	7	1.2 (0.0–14.3)
Mining and extracting	26	56	1.5 (0.9–2.8)	20	1.8 (1.1–4.0)
Construction	17	171	1.1 (0.9–1.7)	55	**1.4** (1.0–2.1)
Food product manufactunng	50	132	1.0 (0.7–1.4)	36	1.2 (0.8–1.9)
Textile manufacturing	26	60	1.0 (0.6–1.7)	19	1.2 (0.7–2.3)
Paper product manufacturing	6	23	0.4 (0.2–1.3)	3	0.3 (0.1–1.2)
Printing and publishing	10	49	0.5 (0.2–1.2)	7	0.6 (0.2–1.4)
Chemical manufactunng	19	65	0.7 (0.4–1.2)	15	0.9 (0.5–1.7)
Petroleum and coal refining and manufacturing	8	18	1.2 (0.4–3.1)	2	**0.4 (0.1–1.9)**
Rubber and plastic product manufactunng	9	30	0.9 (0.4–2.0)	5	0.9 (0.3–2.5)
Leather product manufactunng	1	11	0.2 (0.0–1.6)	1	0.4 (0.0–2.7)
Lumber and wood product manufactunng	25	43	1.0 (0.6–2.0)	20	1.3 (0.8–2.9)
Furniture and fixtures manufacture	9	19	0.8 (0.3–1.9)	5	0.7 (0.2–2.3)
Stone glass. concrete product manufactunng	9	38	0.6 (0.3–1.3)	9	1.0 (0.4–2.3)
Primary metal industries	28	96	0.9 (0.6–1.6)	17	1.0 (0.6–1.8)
Metal product manufactunng	39	105	1.1 (0.8–1.8)	24	1.2 (0.8–2.1)
Machinery manufacturing except electric	30	93	1.1 (0.7–1.8)	19	1.3 (0.7–2.3)
Electrical product manufactunng	15	52	0.8 (0.4–1.5)	10	0.8 (0.4–1.8)
Motor vehicle manufactunng	140	467	0.9 (0.7–1.2)	79	**1.0 (0.7–1.4)**
Aircraft and aircraft pans manufactunng	50	54	1.6 (1.1–2.9)	33	1.6 (1.0–2.9)
Ship and boat manutacturing and repair	15	19	0.6 (0.4–2.1)	7	0.4 (0.2–1.5)
Miscellaneous manufactunng	12	21	1.3 (0.6–3.0)	10	1.8 (0.7–4.7)
Transportation	73	191	0.8 (0.6–1.2)	51	0.9 (0.6–1.4)
Communications and utilities	36	97	0.8 (0.6–1.4)	24	0.8 (0.5–1.5)
Wholesale and retail trade	239	644	0.9 (0.8–1.2)	158	0.9 (0.8–1.4)
Financial. insurance and real estate	65	135	1.1 (0.9–1.8)	48	1.3 (1.0–2.2)
Business services	35	80	1.1 (0.7–1.8)	19	0.9 (0.5–1.7)
Repair services	27	60	1.0 (0.7–1.9)	20	1.2 (0.7–2.5)
Personal services	119	288	0.8 (0.7–1.3)	77	0.9 (0.8–1.5)
Entertainment and recreational	22	50	0.9 (0.5–1.7)	12	0.8 (0.4–1.5)
Health care services	58	162	0.8 (0.6–1.3)	42	1.0 (0.8–1.7)
Professional and related services	85	250	0.8 (0.7–1.2)	53	*0.8* (0.6–1.3)
Public administration	181	528	0.8 (0.7–1.2)	117	0.8 (0.7–1.3)

[a] Odds ratio (OR) adjusted for sex, race. age. and study area and 95% confidence intervals (CI).

operators. When the individual occupations within the latter group were examined, the overall excess risk seen with increasing duration was present for several, but by no means all, of them. The increased risk among forestry and logging workers was present in those employed for < 10 years (no cases and only one control had been in one of these occupations for > 10 years).

The OR associated with industries of a priori interest and those whose confidence limits excluded one in Table II were also analyzed by duration of employment (Table IV). As in Table III, more specific categories were included when informative. Patterns of increasing risk with increasing duration were observed for employment in agricultural production, coal mining, petroleum- and coal-product manufacturing, nonmetal mining, and horticultural services, although the latter were based on small numbers. When the occupations of persons who had been employed in the lumber, wood, petroleum, coal, aircraft, and mining industries were examined, no occupation or group of occupations with similar exposures accounted for the majority of cases,

TABLE III. Relative Risk of Multiple Myeloma by Occupational Group by Duration of Employment

Occupational group	Employed <10 years			Employed 10+ years		
	Cases	Controls	OR (95% CI)[a]	Cases	Controls	OR (95% CI)[a]
Farmers	7	17	1.1 (0.5–3.9)	19	38	1.3 (0.8–2.8)
Farm workers and gardeners	28	74	0.9 (0.6–1.6)	29	64	1.1 (0.7–2.0)
Farm laborers	21	46	1.2 (0.7–2.5)	18	25	1.8 (1.0–4.0)
Unpaid farm family members	4	21	0.6 (0.2–1.8)	11	30	1.0 (0.5–2.2)
Gardeners	4	10	0.7 (0.1–2.5)	1	8	0.2 (0.0–1.6)
Forestry and logging occupations	10	6	3.4 (1.3–17.0)	0	1	0.0 (0.0–29.3)
Carpenters	7	18	0.8 (0.3–2.4)	10	18	1.1 (0.5–3.5)
Precision wood workers	1	2	1.2 (0.0–25.0)	1	0	Inf (0.0–In0
Painters	15	29	1.4 (0.6–2.8)	16	11	4.1 (1.8–10.4)
Construction and maintenance	11	16	1.9 (0.8–4.5)	11	8	3.7 (1.3–11.0)
Manufactured articles	5	14	0.8 (0.2–2.8)	5	3	4.8 (1.1–28.8)
Fire fighting and prevention occupations	1	2	0.9 (0.0–22.3)	4	3	2.9 (0.4–21.6)
Mining occupations	12	25	1.4 (0.7–3.4)	6	11	1.7 (0.7–7.1)
Metal- and plastic-working machine operators	24	52	1.4 (0.8–2.4)	18	32	2.0 (1.1–3.9)
Metal job and die setters	7	4	1.9 (0.2–11.9)	4	4	3.5 (0.7–17.1)
Filers, polishers. sanders. and buffers	1	4	0.4 (0.0–5.1)	1	1	2.5 (0.1–121)
Drill press operatives	6	7	2.9 (0.8–9.5)	1	5	0.7 (0.0–7.0)
Grinding machine operatives	7	14	1.7 (0.6–4.7)	6	15	1.4 (0.5–4.0)
Punch and stamping press operatives	3	8	1.1 (0.2–4.6)	3	2	2.2 (0.3–17.0)
Riveters and fasteners	5	9	1.3 (0.3–4.5)	1	0	Inf (0.1–Inf)

[a]Odds ratio (OR) adjusted for sex. race, age. and study area and 95% confidence intervals (CI).

and those at excess risk were often employed in administrative as well as blue collar jobs.

In an earlier analysis of data from this study, **Moms** et al. [19861 found increased risks associated with self-reported "high" exposure (either at home or at work) to paints and/or solvents (OR = 1.6, 95% CI = 1.1–2.4) and pesticides (OR = 2.6, 95% CI= 1.5–4.6). To determine if the excess risks observed among painters and persons employed in agricultural production were due to these exposures, data from the work history and self-reported exposure portions of the interview were combined. The risk observed among painters who had reported "high" exposure to paints and/or solvents (OR = 2.3) differed little from painters who did not (OR = 2.0) when **all** respondents were considered (Table **V).** In contrast, much of the excess risk of myeloma among persons who had worked in the agricultural industry was concentrated in those who had claimed "high" exposure to pesticides (Table **VI).**

The risk associated with employment in jobs with exposure to radiation could not be assessed because too few workers could be identified on the basis of job title or industry alone. **A** history of employment as an X-ray technician was reported by one case and one control, but no study participants reported having been employed as radiologists and none who had been utility workers reported having worked in a nuclear power plant.

DISCUSSION

There are limitations that should be kept in mind when reviewing the results of this study. Occupation is likely a poor surrogate for specific exposures that may influence the occurrence of multiple myeloma. To the extent that occupational and

TABLE IV. Relative Risk of Multiple Myeloma by Industry Group by Duration of Employment

Industry group	Employed <10 years			Employed 10+ years		
	Cases	Controls	OR (95%CI)[a]	Cases	Controls	OR (95%CI)[a]
Agnculture	34	81	1.1 (0.8–2.0)	50	100	1.3 (1.0–2.2)
Agricultural production	29	75	1.1 (0.7–1.9)	48	95	1.3 (1.0–2.3)
Agricultural services	3	5	0.7 (0.1–5.1)	0	2	0.0 (0.0–24.6)
Horticultural services	4	7	1.3 (0.3–5.7)	2	4	1.6 (0.2–10.6)
Forestry	4	4	2.1 (0.3–13.0)	0	0	—
Lumber and wood product manufacturing	21	32	1.3 (0.7–2.7)	4	11	0.6 (0.1–1.9)
Mining and extracting	14	34	1.3 (0.6–2.7)	12	22	1.9 (1.0–5.2)
Metal mining	4	11	1.2 (0.3–4.6)	4	12	1.1 (0.4–6.2)
Coal mining	6	16	1.2 (0.4–3.5)	6	7	2.9 (0.8–9.9)
Oil and natural gas extraction	2	3	1.6 (0.1–18.5)	0	2	0.0 (0.0–26.7)
Non-metal mining and quarrying	3	5	1.9 (0.4–10.0)	2	1	5.7 (0.1–184)
Paper product manufacturing	2	20	0.2 (0.0–1.0)	4	3	1.5 (0.2–9.7)
Pulp. paper. and paperboard mills	1	4	0.3 (0.0–3.5)	2	2	0.6 (0.0–7.7)
Paperboard containers and boxes	0	8	0.0 (0.0–1.5)	2	1	4.3 (0.2–263)
Miscellaneous paper and pulp products	1	8	0.4 (0.0–3.0)	0	0	—
Petroleum and coal refining and manufacturing	4	12	0.8 (0.2–3.0)	4	6	1.9 (0.4–8.4)
Petroleum refining	1	6	0.5 (0.0–4.2)	0	2	0.0 (0.0–21.1)
Petroleum- and coal-product manufacturing	3	6	1.2 (0.2–6.0)	4	4	2.6 (0.5–14.6)
Rubber- and plastic-product manufactunng	6	19	0.9 (0.3–2.6)	3	11	0.9 (0.2–3.4)
Aircraft and aircraft parts manufacturing	30	40	1.7 (1.0–3.1)	20	14	1.3 (0.8–4.5)

[a]Odds ratio (OR) adjusted for sex. race. age. and study area and 95% confidence intervals (CI).

industrial categories combined jobs with heterogeneous exposures, misclassification was introduced. Even within specific occupations or industries, all workers would not have the same level or type of exposures. It is not possible to evaluate the direction and magnitude of bias that might be introduced by this misclassification. However, it seems likely that such misclassification would be nondifferential with regard to case/control status and so would likely serve to minimize apparent case-control differences and bias the observed relative risks towards the null value. Tables V and VI present examples of the potential effects of such misclassification.

Selective recall of past events is another potential source of bias. Given that multiple myeloma is not widely considered to be an occupational disease, it seems unlikely that cases would selectively recall employment in any one job or group of occupations, although it could be posited that cases may be more likely to remember jobs held for shorter periods of time or farther in the past. However, the number and length of jobs reported by self-respondent cases was quite similar to that of control subjects, while surrogate respondents for the deceased cases provided a less detailed work history. Thus it seems unlikely that the excess risks observed in this study were a result of recall bias.

A last limitation is that this study examined a large number of potential associations, and, by chance alone, some may appear elevated or depressed. For this reason, attention in this paper has focused on occupations and industries that were suspected, a priori, to be associated with an elevated risk of multiple myeloma. Associations that have not been observed in previous studies should be considered more cautiously.

The results of these analyses provide support for a number of associations

TABLE V. Relative Risk of Multiple Myeloma Associated With Employment as a Painter and Self-Reported Exposures to Paint or Solvents

Exposure group		All respondents			Self-responding cases only	
Ever employed as a painter	Reported high exposure to paints or solvents	Cases	Controls	OR (95% CI)[a]	Cases	OR (95% CI)[a]
No	**No**	**1,619**	**592**	**1.0** (reference)	**427**	1.0 (reference)
No	Yes	33	60	**1.5 (0.9-2.5)**	**23**	**1.6** (1.0–3.2)
Yes	**No**	**14**	**19**	**2.0 (0.8-4.5)**	**8**	**1.9 (0.6-5.5)**
Yes	Yes	**17**	**21**	**2.3** (1.1–4.9)	**14**	**3.1 (1.5-7.5)**

[a]Odds ratio (OR) adjusted for sex. race, age. and study area and **95%** confidence intervals (CI).

TABLE VI. Relative Risk of Multiple Myeloma Associated With Employment in Agriculture and Self-Reported Exposures to Pesticides

Exposure group		All respondents			Self-responding cases only	
Ever employed in agriculture	Reponed high exposure to pesticides	Cases	Controls	OR (95% CI)[a]	Cases	**OR (95% CI)[a]**
No	**No**	**596**	**1,494**	1.0 (reference)	**402**	1.0 (reference)
No	Yes	**19**	**19**	2.1 **(1.0-4.8)**	**13**	**2.1** (0.9–5.6)
Yes	**No**	**68**	**163**	1.1 (0.9–1.8)	**49**	1.4 (1.0-2.3)
Yes	Yes	**9**	**7**	**5.2 (1.6-21.1)**	**8**	**7.9 (2.4-46.1)**

"Odds ratio (OR) adjusted for sex, race. age. and study area and **95%** confidence intervals (CI)

observed by previous investigators. In this study, small excess risks were associated with employment as a farmer or farm worker or in agricultural production or horticultural services, and these risks tended to increase with increasing duration of employment. However, no excess was observed among gardeners and unpaid family members. The magnitude of the increased risk observed in many previous studies also was small, but relatively consistent [Blair and Hoar Zahm, 1991]. The agent or agents possibly responsible have not been identified, although attention has focused primarily on insecticides and herbicides [Blair and Hoar Zahm, 1991; Pearce and Reif, 1990]. The work history information utilized for the present analysis lacked the detail necessary to shed further light on this issue. However, the excess risk was much higher among agricultural workers who reported that they had been highly exposed to pesticides than for those who did not. Boffetta et al. [19891 observed a similar pattern among participants in the American Cancer Society Cancer Prevention Study; among farmers who reported exposure to pesticides. the OR was 4.3, while a much smaller risk was observed among farmers who reported no exposure (OR = 1.7).

An excess risk of multiple myeloma among painters also was observed. While solvent exposure is well recognized among painters, paint is actually a complex mixture of pigments, solvents, binders, and additives, and possible exposures include a number of established carcinogens such as chromates, asbestos, and formaldehyde [IARC, 19891. The fact that the risk was elevated for both those who did and did not

as a Painter and

Self-responding cases only	
es	OR (95% CI)[a]
7	1.0 (reference)
3	1.6 (1.0–3.2)
5	1.9 (0.6–5.5)
4	3.1 (1.5–7.5)

intervals (CI).

in Agriculture

Self-responding cases only	
es	OR (95% CI)[a]
2	1.0 (reference)
3	2.1 (0.9–5.6)
9	1.4 (1.0–2.3)
8	7.9 (2.4–46.1)

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report high exposure to solvents and/or paint may indicate that the association is due to chronic exposures that may not be described by painters as being "high." Evidence also was found to support the existence of an excess risk among persons employed as firefighters and in the petroleum- and coal-products manufacturing industries. In both instances, there was a suggestion, based on very small numbers, of increasing risk with increasing duration of employment. No evidence was found for an excess risk among refinery workers.

The situation with respect to wood-related occupations and industries is less clear. While an excess risk was observed among persons employed in forestry and logging occupations, no excess was apparent among carpenters and persons employed in lumber and wood products manufacturing. This agrees with the results of Flodin et al. [1987], who found an excess risk in workers exposed to fresh wood. Workers in forestry and logging may also be exposed to pesticides such as chlorophenols.

Associations also were found in this analysis that have not been reported by previous investigators. Metal- and plastic-working machine operators, a category that includes grinding machine, drill press, and stamping press operators, were at higher risk for multiple myeloma. While an excess risk among some related occupational groups has been observed, this has not been a consistent finding of previous studies. Potential exposures that might explain the excess are difficult to determine. Many workers in this group are likely to be exposed to cutting fluids, metal dusts, or metal fumes. However, other categories with similar exposures, such as precision metal workers and metal- and plastic-processing machine operators, did not have elevated risks in this analysis.

The excess observed among workers in the aircraft and parts industry also was unexpected. Garabrant et al. [1988] did not find an excess risk among workers in this industry in southern California, but a study of aircraft maintenance workers by Spirtas et al. [1991] found an elevated risk among workers exposed to solvents. This industry has a diverse set of potential exposures [Garabrant et al., 19881. However, cases did not cluster in any one occupation within the industry.

In summary, this study lends further support to the findings of some previous studies concerning associations between multiple myeloma and employment as painters and agricultural workers. Some evidence, based on small numbers, was found for an excess risk among firefighters and persons employed in petroleum- and coal-products manufacturing. Although an excess risk was observed among foresters and loggers, little other evidence was found to support the previously noted association with wood exposure. No evidence for an association with employment in the rubber or petroleum refining industries was found. The other associations observed in these analyses deserve evaluation in future studies.

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