American Journal of Industrial Medicine 18:641–652 (1990)

Mortality of U.S. Embalmers and Funeral Directors

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The causes of mortality of 3,649 white and 397 non-white male U.S. embalmers and funeral directors, who had died between 1975 and 1985, were examined in a proportional mortality study. Non-significant excesses were found for malignancies of the buccal cavity and pharynx (PMR = 120) and for nasopharyngeal cancer (PMR = 216). No sinonasal cancers were observed, while 1.7 were expected. A statistically significant excess of colon cancer (PMR = 127) was found and a non-significant excess of brain and other CNS cancer was noted among whites only (PMR = 123).

Statistically significant excesses of malignancies of the lymphatic and hematopoietic systems were found in whites (PMR = 131) and non-whites (PMR = 241). Myeloid leukemia (PMR = 157) and leukemia of other and unspecified cell types (PMR = 228) were in excess, while no excess of lymphatic leukemia was noted. Elevations in risk were also found for non-Hodgkin's lymphoma, polycythemia vera, and myelofibrosis. Non-whites showed a marked excess of multiple myeloma (PMR = 369).

Chronic nephritis was in excess among whites (PMR = 215) and non-whites (PMR = 257). No excess of cirrhosis of the liver was found.

Excesses of malignancies of the lymphatic and hematopoietic systems could not be directly related to job held in the funeral industry. Further case-control studies are planned to rule out the possibility that the observed associations are artifactual, by assessing the association between specific work practices and disease risk.

Key words: epidemiology, neoplasm, embalmer, formaldehyde, CNS cancer, leukemia, occupational mortality

INTRODUCTION

Experimental studies have shown the development of nasal carcinomas in rats after long-term inhalation exposure to formaldehyde vapor at exposure levels ranging from 6 to 15 ppm [Albert et al., 1982; Tobe et al., 1985; Kerns et al., 1982] and after short-term inhalation exposure of about 20 ppm [Feron et al., 1988]. Epidemiologic studies have provided only limited evidence for an association between formaldehyde exposure and respiratory cancer risk in humans [IARC, 1987], particularly for sinonasal [Olsen et al., 1984; Olsen and Asnaes, 1986; Hayes et al., 1986], nasopharyngeal

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Accepted for publication March 2, 1990.

[Roush et al., 1987; Vaughan et al., 1986a,b; Blair et al., 1987], and buccal cavity and pharynx cancer [Stayner et al., 1988].

Epidemiologic studies also noted excesses for leukemia and cancers of the brain and other parts of the central nervous system among funeral directors/embalmers (FD/E) [Walrath and Fraumeni, 1983; 1984; Levine et al., 1984; Milham, 1976], pathologists [Harrington and Shannon, 1975; Harrington and Oakes, 1984; Matanoski, 1989], and anatomists [Stroup et al., 1986]. These findings have emphasized the possible association of cancer risk with formaldehyde exposure in these jobs, although studies of industrial workers exposed to formaldehyde have not generally shown excesses of cancer at these sites [IARC, 1987].

To further elaborate on cancer excesses among professional workers exposed to formaldehyde, we have assembled a large series of deceased embalmers and funeral directors from multiple sources throughout the United States which will allow examination of the risk for specific cell types of leukemia and other lymphatic and hematopoietic system malignancies and allow assessment of potential subgroups at risk.

MATERIALS AND METHODS

For this study, subjects who died between 1975 and 1985 and who had worked in funeral services were identified from a number of sources. Licensing boards and state funeral directors' associations from 32 states and the District of Columbia provided listings of deceased or inactive (nine states) members of the profession. Nine states and New York City directly provided death certificates for deceased funeral directors/embalmers based on occupational data available on the certificates. For two states, both listings and death certificates were provided. In addition, the National Funeral Directors' Association (NFDA) provided 3,291 names of members who had died in the U.S.

After duplicates were removed, 6,651 potential study subjects were identified, of which death certificates were obtained for 5,265 (79%). The actual percent of deaths for which a death certificate could not be found was lower than 21% as some state professional organizations only provided lists of inactive members, not all of whom were deceased, and the death year for others was found to be prior to 1975. The certificates obtained were then coded for underlying cause of death by a qualified nosologist according to the rules in effect at the time of death and assigned codes according to the *International Classification of Diseases, 8th Revision* [U.S. National Center for Health Statistics, 1967]. After exclusion of 449 decedents who had been included in prior studies of the funeral service industry in New York [Walrath and Fraumeni, 1983] and California [Walrath and Fraumeni, 1984], 376 subjects who probably did not work as funeral directors/embalmers, two subjects of unknown race, six of unknown age at death, and 386 females, there were 4,046 death certificates of males available for analysis, including 3,649 whites and 397 (11%) non-whites. The primary sources of study group records were local boards (n = 1,950), the NFDA (n = 1,202), and state offices of vital statistics (n = 894).

Observed numbers of deaths by cause were compared with expected numbers of deaths on the basis of 5-year age- and calendar-year specific proportions of deaths among appropriate race and sex groups from the U.S. general population. The proportionate mortality ratio (PMR ($\times$ 100)) was calculated as the ratio of observed to expected deaths [Monson, 1974]. For selected analyses, the proportionate cancer mortality ratio (PCMR ($\times$ 100)) was calculated, excluding non-cancer causes of death

from the proportionate calculations [Walker, 1986]. To calculate confidence limits (95%) for the PMR and PCMR, exact methods [Haenzel et al., 1962] were used for small numbers (< 16 deaths), while approximate methods [Breslow and Day, 1987] were otherwise used.

RESULTS

In Table I, the number of deaths by cause and the associated PMRs are shown for white and non-white males. Among white males, there was a significant excess of deaths due to malignant neoplasms (PMR = 107), diseases of the circulatory system (PMR = 105), chronic rheumatic heart disease (PMR = 226), arteriosclerotic heart disease (PMR = 113), and suicide (PMR = 130). Significant deficits in deaths for white males are noted for mental disorders (PMR = 54), diseases of the respiratory system (PMR = 85), including pneumonia (PMR = 74), for all external causes of death (PMR = 86), including accidents (PMR = 72), and for symptoms and ill-defined conditions (PMR = 57). For non-whites, there is a significant excess of arteriosclerotic heart disease (PMR = 145) and a significant deficit of respiratory disease (PMR = 53). Chronic nephritis is in excess among whites (PMR = 215) and non-whites (PMR = 257), with a PMR = 224 (95% C.L.: 116–392) for the combined group. Death due to cirrhosis of the liver is not in excess for either race group.

Table II displays results for selected malignancies. Non-significant excesses are found for malignancies of the buccal cavity and pharynx and, specifically, for the nasopharynx, for both whites and non-whites. For the combined group of whites and non-whites, the PMR for buccal cavity and pharyngeal cancer was 120 (95% C.L.: 81–171) and for nasopharyngeal cancer the PMR was 216 (95% C.L.: 59–554). No sinonasal cancers were observed although 1.7 deaths were expected in the combined study group. Excesses are also found for cancers of the digestive system among whites and non-whites, with a statistically significant excess for colon cancer (PMR = 231) in non-whites and in the combined study group, PMR = 127 (95% C.L.: 104–153).

A non-significant excess of brain and other CNS cancer is noted among whites (PMR = 123). Additionally, two whites had died of benign tumors of the brain and other parts of the nervous system (ICDA 8: 225), and three had died of brain neoplasms of unspecified nature (ICD 8: 238.1). Combining all deaths due to tumors of the nervous system for whites, the PMR = 118 (95% C.L.: 79–170). No nervous system tumor deaths were identified among non-whites, while 1.2 were expected. Statistically significant excesses of malignancies of the lymphatic and hematopoietic systems were found in whites (PMR = 131) and in non-whites (PMR = 241). For the combined study group, the risk for these diseases was PMR = 139 (95% C.L.: 115–163). The proportional cancer mortality ratio for malignancies of the lymphatic and hematopoietic system was significantly elevated (PCMR = 133, 95% C.L.: 110–160), while no excess was shown for malignancies of the brain and other CNS (PCMR = 109; 95% C.L.: 70–162).

In Table III, a number of factors are examined in association with risk of malignancies of the lymphatic and hematopoietic system and of the brain and other parts of the CNS. Funeral directors are at a statistically significant excess risk for lymphatic and hematopoietic system malignancies (PMR = 156). Embalmers and "other" subjects have non-statistically significant excess risks for these diseases.

TABLE I. Number of Deaths Observed (Obs) and Expected (Exp), Proportional Mortality Ratios (PMR), and Confidence Limits (95%) Among U.S. White and Non-White Embalmers and Funeral Directors, 1975–1985

	Whites				Non-whites			
Causes of death (ICDA No.)	Obs	Exp	PMR	(C.L.: 95%)	Obs	Exp	PMR	(C.L.: 95%)
All infective and parasitic diseases (000–136)	18	25.3	71	42–112	4	5.8	69	19–177
All malignant neoplasms (140–209)	900	838.1	107	101–115	102	94.6	108	87–131
Benign neoplasms (210–228)	9	9.6	93	43–177	0	1.1		
Endocrine, nutritional and metabolic diseases, and immunity disorders (240–279)	68	64.9	105	81–133	7	9.8	72	29–148
Diabetes mellitus (250)	57	51.3	111	84–144	6	7.5	80	29–175
Diseases of the blood and blood forming organs (280–289)	9	9.1	99	45–189	1	1.2	87	2–482
Mental disorders (290–315)	12	22.1	54	28–95	2	4.4	45	5–163
Diseases of the nervous system and sense organs (320–389)	22	33.2	66	42–100	3	3.3	91	19–266
Diseases of the circulatory system (390–458)	1,982	1,895.1	105	100–109	211	186.4	113	98–130
Chronic rheumatic heart disease (393–398)	30	13.3	226	152–323	0	0.8		
Ischemic heart disease (410–414)	1,418	1,254.9	113	107–119	135	92.9	145	122–172
Vascular lesions of the CNS (430–439)	253	248.1	102	90–115	32	35.6	90	61–127
Diseases of the respiratory system (460–519)	233	274.3	85	74–97	13	24.6	53	28–91
Pneumonia (480–486)	63	85.7	74	56–94	5	11.3	44	14–103
Emphysema (492)	48	46.6	103	76–136	1	2.2	46	1–255
Asthma (493)	2	3.8	53	6–191	1	0.7	152	2–845
Diseases of the digestive system (520–577)	126	146.9	86	71–102	12	16.7	72	37–126
Gastric and duodenal ulcer (531–532)	10	13.4	74	36–137	0	1.2		
Cirrhosis of the liver (571)	67	73.7	91	70–116	4	8.2	49	13–125
Diseases of the genitourinary system (580–629)	37	44.5	83	59–115	11	9.4	117	59–210
Chronic nephritis (582)	9	4.2	215	98–408	3	1.2	257	52–750
All external causes of death (E800–E999)	201	233.8	86	75–99	25	27.7	90	58–133
All accidents (E800–E949)	106	147.3	72	59–87	13	16.3	80	42–136
Suicide (E950–E959)	74	56.8	130	102–164	4	1.8	217	58–557
Symptoms, senility, and ill-defined conditions (780–796)	22	38.5	57	36–86	5	10.2	49	16–114
Other and unspecified	10				1			
Total	3,649				397			

Significant excesses for lymphatic and hematopoietic malignancies occurred in the Midwest (PMR = 192) and the South (PMR = 143) but not in the Northeast (PMR = 106) or West (PMR = 87). The risk for lymphatic and hematopoietic cancer was elevated for different ages of death, with the highest risks in the 60–74 year age group (PMR = 172). The mortality results are similar for data derived from local and from the National Boards of Funeral directors. For records derived directly from vital

TABLE II. Number of Deaths Observed (Obs) and Expected (Exp) Due to Malignant Neoplasms, Proportional Mortality Ratios (PMR), and Confidence Limits (95%) Among U.S. White and Non-White Embalmers and Funeral Directors, 1975–1985

	Whites				Nonwhites			
Causes of death (ICDA No.)	Obs	Exp	PMR	(C.L.: 95%)	Obs	Exp	PMR	(C.L.: 95%)
Buccal cavity and pharynx (140–149)	26	21.8	119	78–174	4	3.2	125	34–320
Nasopharynx (147)	3	1.6	189	39–548	1	0.25	400	10–2,229
Digestive organs and peritoneum (150–159)	235	215.1	109	96–124	32	26.9	119	81–168
Esophagus (150)	22	19.1	115	72–173	1	5.0	20	1–110
Stomach (151)	22	31.0	71	44–107	2	5.4	37	4–134
Colon (153)	95	80.5	118	95–144	16	6.9	231	132–376
Rectum (154)	22	19.6	112	70–170	4	1.7	234	64–600
Liver and gall bladder (155–156)	16	16.1	100	57–162	1	2.5	40	1–221
Pancreas (157)	51	42.7	119	89–157	8	4.8	167	72–329
Respiratory system (160–163)	294	307.5	96	85–107	23	32.3	71	45–107
Sinonasal (160)	0	1.5	—		0	0.16	—	
Larynx (161)	7	10.9	64	26–133	0	1.6		
Trachea, bronchus and lung (162)	285	294.0	97	86–109	23	30.5	75	47–113
Bone (170)	2	2.1	93	11–336	0	0.2	—	
Skin (172–173)	19	14.2	134	81–209	0	0.4	—	
Breast (174)	2	1.0	200	24–722	0	1.3	—	
Prostate (185)	79	74.8	106	84–132	19	14.0	135	82–212
Testis (186)	1	2.2	45	1–248	0	0.2	0	0–1,574
Bladder (188)	23	26.3	88	55–131	0	1.6	0	0–2,177
Kidney (189)	25	19.8	126	82–187	2	1.3	152	18–550
Eye (190)	2	0.6	362	44–1,308	0	0.0	—	
Brain and other CNS (191–192)	24	19.4	123	80–184	0	0.8	—	
Thyroid (193)	3	1.2	237	49–693	0	0.1	—	
Lymphoietic and hematopoietic (200–209)	100	76.4	131	106–159	15	6.2	241	135–397

statistics, no excess is shown for lymphatic and hematopoietic malignancies (PMR = 101), while a significant excess is shown for brain and other CNS (PMR = 220). For cancers of the brain and other CNS, no significant excesses are noted, by occupation, region, or age at death, although the risk is somewhat higher in younger men (PMR = 169).

The risk associated with specific cell type of leukemia and of other lymphatic and hematopoietic malignancies is shown in Table IV. Of the leukemias, statistically significant excesses occurred for myeloid leukemia (PMR = 157) and for leukemia of other and unspecified cell types (PMR = 228). This excess is generally found for whites and non-whites. No excess was noted for multiple myeloma in whites, while a marked excess was found in non-whites (PMR = 369). Although not statistically significant, elevations in risk among whites were also found for non-Hodgkin's lymphoma (PMR = 129), polycythemia vera (PMR = 405), and myelofibrosis (PMR = 163). Mortality from Hodgkin's disease and lymphatic leukemia was not excessive in either whites or non-whites. Further analysis of the leukemias by the acute and chronic forms did not suggest a difference in risk on this basis. Both acute (PMR = 152, 95% C.L.: 85–252) and chronic (PMR = 184, 95% C.L.: 79–362) myeloid leukemia were in excess.

TABLE III. Number of Deaths Observed (Obs) and Expected (Exp) Due to Malignancies of the Lymphatic and Hematopoietic Systems and of the Brain and Central Nervous System, Proportional Mortality Ratios (PMR), and Confidence Limits (95%) Among U.S. Embalmers and Funeral Directors, by Selected Characteristics, 1975–1985

	Lymphatic and hematopoietic (ICDA 200–209)				Brain and CNS (ICDA 191–192)			
Characteristics	Obs	Exp	PMR	(C.L.: 95%)	Obs	Exp	PMR	(C.L.: 95%)
Occupation (death certificate)								
Embalmer	23	18.7	123	78–185	6	4.9	123	45–267
Funeral director	78	50.1	156	123–194	17	12.8	132	77–212
Other	12	9.2	130	67–228	1	2.5	40	1–222
Region								
Northeast	19	17.8	106	64–166	6	4.6	130	48–284
Midwest	49	25.4	192	142–255	8	6.4	124	54–245
South	41	28.7	143	102–194	9	7.5	120	55–227
West	5	5.7	87	28–204	1	1.6	62	2–345
Age at death								
<60	26	19.2	135	88–198	14	8.3	169	92–283
60–74	66	38.3	172	133–219	9	10.0	90	41–171
75+	23	19.8	116	74–174	1	1.9	51	1–287
Source								
Local boards	63	37.8	167	128–213	10	10.1	99	48–182
NFDA	35	23.4	150	104–208	5	6.1	82	27–191
Vital records	17	16.8	101	59–162	9	4.1	220	101–417

DISCUSSION

Because of the large number of study subjects included for analysis, the PMRs for common causes of death which moderately differ from the expected value may be statistically significant. Overall, in this study, proportional mortality for non-malignant diseases is about as expected, based on mortality in the U.S. population, with some excess of diseases of the circulatory system, particularly in non-whites, and some deficit in respiratory disease.

Risk for a number of cancer sites is described in this study. Considering the route of exposure, the experimental evidence of nasal cancer development in rats [Albert et al., 1982; Kerns et al., 1982], and the highly reactive nature of formaldehyde with biologic tissue [Heck, 1982], the upper respiratory tract and oral cavity would be the most likely sites for cancer development in humans exposed to this chemical. We noted no excess of sinonasal cancer. Among the large numbers of specific occupational groups studied in previous investigations [IARC, 1987], no excesses of sinonasal cancer have been found. Only in case-control studies which included subjects with a broad spectrum of occupational exposures to formaldehyde have excesses been noted [Olsen and Asnaes, 1986; Hayes et al., 1986].

Others [Vaughn et al., 1986a,b; Walrath and Fraumeni, 1983, 1984; Blair et al., 1986; Stayner et al., 1988] have noted excesses of cancers of the buccal cavity and pharynx in formaldehyde-exposed subjects. In the study of Stayner et al. [1988], the findings for the buccal cavity were statistically significant. Specific excesses have also been noted for cancers of the nasopharynx in formaldehyde-exposed subjects [Vaughn et al., 1986a,b; Blair et al., 1987]. The findings of the present study, although based on small numbers, are consistent with this latter association.

TABLE IV. The Number of Deaths (Obs) and Expected (Exp) Due to Selected Malignant Neoplasms, Proportional Mortality Ratios (PMR), and Confidence Limits (95%) Among U.S. Embalmers and Funeral Directors, 1975–1985

		Whites				Nonwhites				Total group			
Cause of death	ICD:8	Obs	Exp	PMR	(C.L.: 95%)	Obs	Exp	PMR	(C.L.: 95%)	Obs	Exp	PMR	(C.L.: 95%)
Lymphatic and hematopoietic malignancies	200–209	100	76.4	131	(106–159)	15	6.2	241	(135–397)	115	82.7	139	(115–167)
Hodgkins disease	201	3	4.0	76	(16–222)	0	0.2	—	—	3	4.2	72	(15–210)
Non-Hodgkin's lymphoma	200,202	33	25.6	129	(89–181)	1	1.4	69	(2–389)	34	27.1	126	(87–176)
Lymphosarcoma and reticulosarcoma	200	11	10.2	108	(54–193)	1	0.5	189	(5–1,051)	12	10.7	112	(58–196)
Multiple myeloma	203	12	12.4	97	(50–169)	8	2.2	369	(159–726)	20	14.6	137	(84–212)
Other lymphoid lymphoma	202	22	15.4	143	(89–216)	0	0.9	—	—	22	16.3	135	(84–201)
Lymphatic leukemia	204	5	8.7	57	(19–133)	2	0.7	299	(36–1,077)	7	9.4	74	(29–153)
Myeloid leukemia	205	23	14.3	161	(102–241)	1	0.9	106	(2–593)	24	15.3	157	(101–234)
Other and unspecified leukemia	206,207	17	8.2	208	(121–334)	3	0.6	492	(101–1,436)	20	8.8	228	(139–352)
Polycythemia vera	208	3	0.7	405	(84–1,184)	0	0.0	—	—	3	0.8	390	(80–1,138)
Myelofibrosis	209	4	2.5	163	(44–416)	0	0.2	—	—	4	2.6	262	(42–391)

In Table V, the mortality results in this study for malignancies of the brain and CNS and of the lymphatic and hematopoietic system are compared to the results from previous studies among funeral directors/embalmers and among other professionals who may have similar exposures. Cause of death rubrics are regrouped for comparison with these studies. The present study, in contrast to the previous studies, includes only deaths from a recent time period.

Previous studies have consistently reported larger excesses of malignancies of the brain and other parts of the central nervous system in these occupational groups. In the present study there was a non-significant 23% excess among whites, while no cases were identified in non-whites. Although the present finding is not entirely inconsistent with previous studies, it does not provide strong support for the association.

In this study, the risk for leukemia was significantly elevated in both whites and non-whites. The results are remarkably consistent with previous findings for the professional groups, in both PMR and SMR studies. Because of the large size of our study, we were better able than previous investigators to examine risk associated with specific histologic types of leukemia. In our study, risk was associated with both the acute and chronic myeloid forms of leukemia, but not with lymphatic leukemia, which had a deficit in whites. These findings are consistent with reports on FD/E by Walrath and Fraumeni, [1983, 1984] who also reported a preponderance of myeloid leukemia. For anatomists, Stroup et al. [1986] reported a eight-fold excess of chronic myeloid leukemia, based on three deaths.

There is no evidence from the current study or from prior studies that lymphosarcoma and reticulosarcoma or Hodgkin's disease are related to employment in these

TABLE V. Summary Results of Proportional Mortality (PMR) and Standardized Mortality (SMR) Studies Among Funeral Directors/Embalmers (FD/E) and Among Other Professional Groups Who Handle Human Tissue

	Funeral directors and embalmers						Pathologists			Anatomists
Author [year]:	Present study		Walrath and Fraumeni [1983]	Walrath and Fraumeni [1984]	Milham [1976]	Levine et al. [1984]	Harrington and Shannon [1975]	Harrington and Oakes [1984]	Matanoski [1989]	Stroup et al [1986]
Study region	U.S. white	U.S. nonwhite	New York	California	Washington state	Ontario	U.K.	U.K.	U.S.	U.S.
No. of deaths	3,649	397	1,132	1,007	222	319	156	126	3,644	738
Time period	1970–85	1970–85	1925–80	1925–80	1950–71	1928–77	1955–73	1974–80	1912–78	1888–1979
RR estimates	PMR	PMR	PMR	PMR	PMR	SMR	SMR	SMR	SMR	SMR
Cause of death (ICDA No.)	Study results: RR (observed deaths)									
Brain and CNS (191–192)	123 (24)	— (0)	156 (9)	194[a] (9)	100 (1)	115 (3)	NR[b]	331[a] (4)	141 (13)	270[a] (10)
Lymphatic and hematopoietic (200–209)	131[a] (100)	241[a] (15)	121 (25)	122 (19)	192 (7)	124 (8)	200[a] (8)	67 (2)	122 (64)	120 (18)
Lymphosarcoma & reticulosarcoma (200)	108 (11)	189 (1)	108 (5)	97 (3)	100 (1)	NR	NR	NR	111 (15)	70 (2)
Hodgkin's disease (201)	76 (3)	— (0)	89 (2)	— (0)	NR	NR	142 (1)	NR	34 (2)	— (0)
Other lymphatic cancer (202, 203,208,209)	119 (37)	242[a] (8)	123 (6)	133 (4)	NR	NR	NR	NR	153 (16)	200 (6)
Leukemia	144[a] (45)	272[a] (6)	140 (12)	175[a] (12)	299 (5)	160 (4)	62 (2)	90 (1)	168[a] (31)	150 (10)

[a] $p < .05$.
[b] NR: not reported.

professions. However, Blair et al. [1986] reported an excess of Hodgkin's disease in industrial workers exposed to formaldehyde. As have others [Walrath and Fraumeni, 1983, 1984; Stroup et al., 1986], we also found an excess of "other lymphatic cancers." The finding that non-white FD/E are at excess risk for multiple myeloma is noteworthy because of the higher rates for this disease among U.S. blacks than for whites [Schottenfeld and Fraumeni, 1982].

Although the excesses for leukemia and "other lymphatic cancers" in funeral directors/embalmers, pathologists, and anatomists are consistent with an association with formaldehyde exposure, similar results have generally not been found for industrial workers exposed to formaldehyde [IARC, 1987]. In only one study of industrial garment workers [Stayner et al., 1988] have excesses for these sites been found. Leukemia was significantly elevated among workers with 20 or more years of latency and other lymphopoietic neoplasms were significantly elevated among workers with 10 or more years exposure. Four of the five other lymphopoietic neoplasms reported in this study were multiple myelomas. However, no separate risk estimate was given for this disease.

Overall in the present investigation, mortality due to most non-malignant causes of death was not exceptional. Levine et al. [1984] had noted an excess of deaths due to cirrhosis of the liver among Ontario embalmers, but the present study did not support this finding. In agreement with Levine et al. [1984], however, an excess of chronic rheumatic heart disease was found. We also found an excess for chronic nephritis in both white and non-white FD/E. Blair et al. [1986] found an excess in workers employed in formaldehyde-producing or -using facilities who had been followed for 20+ years (SMR = 188; 95% C.L.: 90–346) (unpublished data). The importance of these findings for non-malignant disease is unclear.

Based upon the limited information available, several factors were examined in association with risk for malignancies of the lymphatic and hematopoietic system and of the brain and other CNS. Our analysis of occupations reported on the death certificate did not show a clear difference in disease risk related to specific occupations in the funeral industry, but duties of embalmers and funeral directors often overlap. The study results show some geographic variation in risk of malignancies of the lymphatic and hematopoietic system, with the highest PMRs being found for the Midwest and South. Other studies have shown excesses for these diseases in New York [Walrath and Fraumeni, 1983] and California [Walrath and Fraumeni, 1984]. We have no explanation for the lack of excesses in the West in this investigation, although few deaths remain after exclusion of those studied by Walrath and Fraumeni [1984]. Excesses of malignancies of the lymphatic and hematopoietic system were reported from funeral director organization sources, while an excess of brain cancer was noted from vital statistics sources. Some other [Walrath and Fraumeni, 1983, 1984], although not all [Milham, 1976; Levine et al., 1984] studies with positive findings relied on funeral director organization sources for notification of deaths.

Studies of embalmers in funeral homes have shown average levels of formaldehyde of 1 ppm or less [Kerfoot and Mooney, 1975; Williams et al., 1984; Moore and Ogrodnik, 1986]. We have recently conducted air monitoring of 24 embalmings in a mortuary college. Low, moderate, or high ventilation was used in each of eight cases. Averaged over the entire embalming procedure, personal exposures ranged from 3.99 ppm for low ventilation to 0.98 ppm for high ventilation. Real-time

monitoring for formaldehyde was also carried out by using a CEA Instruments TGM-555 Toxic Gas Monitor which indicated that short-term high exposures of up to 20 ppm occur.

Drying and hardening powders, which may contain <5% crystalline paraformaldehyde, are another potential source of formaldehyde exposure. We found levels of total dust ranging from 0.07 to 0.78 mg/m^3 (n = 25, mean = 0.42/m^3). Embalmers may also be exposed to phenol, methyl alcohol, glutaraldehyde, and biologic materials, and in the past were exposed to mercury, arsenic, and zinc. In embalming, exposure to radiation from corpses having radiation implants may occur [Laughlin et al., 1968; National Committee of Radiation Protection, 1953]. We have found no evidence that benzene is used in embalming practice. From wipe samples in the embalming room we found blood contamination. This suggests that aerosolization of blood and other biologic tissues may occur, as blood contamination was found at sites where direct dripping would not likely appear. Pathologists and anatomists may use a wide variety of other fixatives, stains, and chemical agents. The major exposures, in common with embalmers, are to formaldehyde and biologic tissues and tissue fixatives such as formaldehyde and possibly glutaraldehyde and phenol.

The data for this study were collected from a number of sources including state vital statistics offices and state and national professional organizations. Each source for identification of study subjects can potentially be associated with biased ascertainment. The professional organizations are, to an important extent, passive recipients of death notifications from their members or had available only information on inactive status in the professional group. Data on occupation and cause of death from vital statistics offices are dependent upon accurate completion of these components of the death certificate. Either differential reporting to the professional organizations of deaths or differential reporting of the occupation and cause of death to vital statistics offices would lead to a biased result.

A bias in proportionate mortality analyses can occur because the basis for comparison is derived from other deaths, rather than from actual mortality rates. If the number of deaths in the study group is low due to causes other than the cause of interest, then the PMR for the cause of interest will be artificially inflated. The concern is that lower rates for major causes of death, such as of the respiratory or circulatory system, may yield inflated PMR estimates for specific cancer sites. This is not indicated in this data set. A PCMR analysis for the major sites of interest showed similar results to the PMR analyses.

Although findings have been remarkably consistent for leukemia and suggestive for other malignancies in the various mortality studies of professionals, it has not been possible to rule out selection bias or to clearly relate disease risk to specific work practices and exposures. For all of these studies, information is lacking on employment duration and on the specifics of the actual materials used and duties performed. We plan further detailed interview studies of next-of-kin and co-workers of cases with CNS cancer or lymphatic and hematopoietic malignancies and of control subjects to better specify these associations.

ACKNOWLEDGMENTS

Data collection for this study was carried out with the assistance of Westat, Inc., Rockville, MD. We thank R. Saal, M. Riscigno, and S. Pratt of Westat, Inc., for their

contribution. We also thank the National Funeral Director's Association and the many state associations of funeral directors and offices of vital statistics for their cooperation in this study.

REFERENCES

Albert RE, Sellakumar AR, Laskin S, Kuschner M, Nelson N, Snyder CA (1982): Gaseous formaldehyde and hydrogen chloride induction of nasal cancer in the rat. JNCI 68:597–603.

Blair A, Stewart PA, O'Berg M, Gaffey W, Walrath J, Ward J, Bales R, Kaplan S, Cubit D (1986): Mortality among industrial workers exposed to formaldehyde. JNCI 76:1071–1084.

Blair A, Stewart PA, Hoover RN, Fraumeni JF, Jr, Walrath J, O'Berg M, Gaffey W (1987): Cancers of the nasopharynx and oropharynx and formaldehyde exposure (letter). JNCI 78:191–193.

Breslow NE, Day NE (1987): "Statistical Methods in Cancer Research. Volume II. The Design and Analysis of Cohort Studies." IARC Sci Publ No. 82. Lyon: International Association for Research on Cancer.

Feron VJ, Bruyntjes JP, Woutersen RA, Immel HR, Appelman LM (1988): Nasal tumors in rats after short-term exposure to a cytotoxic concentration of formaldehyde. Cancer Lett 39:101–111.

Haenzel W, Loveland D, Sirken MG (1962): Lung cancer mortality as related to residence and smoking histories. J Natl Cancer Inst 28:947–1001.

Harrington JM, Shannon HS (1975): Mortality study of pathologists and medical laboratory technicians. Br Med J 2:329–334.

Harrington JM, Oakes D (1984): Mortality study of British pathologists 1974–1980. Br J Ind Med 41:188–191.

Hayes RB, Raatgever JW, de Bruyn A, Gerin M (1986): Cancer of the nasal cavity and paranasal sinuses and formaldehyde exposure. Int J Cancer 37:487–492.

Heck H (1982): Biochemical toxicology of inhaled formaldehyde. Chem Ind Inst Toxicol 2:3–8.

IARC (1987): "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Overall Evaluations of Carcinogenicity. An Update of IARC Monographs Volumes 1 to 42." Lyon: International Association for Research on Cancer.

Kerfoot EJ, Mooney TF (1975): Formaldehyde and paraformaldehyde study in funeral homes. Am Ind Hyg Assoc J 36:533–537.

Kerns WD, Pavkov KL, Donofrio DJ, Gralla EJ, Swenberg JA (1982): Carcinogenicity of formaldehyde in rats and mice after long-term inhalation exposure. Cancer Res 43:4382–4392.

Laughlin JS, Vacirca SJ, Duplissey JF (1968): Exposure of embalmers and physicians by radioactive cadavers. Health Phys 15:451–455.

Levine RJ, Andjelkovich DA, Shaw LK (1984): The mortality of Ontario undertakers and a review of formaldehyde-related mortality studies. J Occup Med 26:740–746.

Matanoski GM (1989): "Risk of Pathologists Exposed to Formaldehyde. Final Report." DHHS Grant No. 5 R01 OH01511-03. Cincinnati, OH: National Institute for Occupational Safety and Health, Centers for Disease Control.

Milham S, Jr (1976): "Occupational Mortality in Washington State, 1950–1971." National Institute for Occupational Safety and Health. Cincinnati, Ohio.

Monson RR (1974): Analysis of relative survival and proportional mortality. Comput Biomed Res 7:325–332.

Moore LL, Ogrodnik EC (1986): Occupational exposure to formaldehyde in mortuaries. J Environ Health 49:32–35.

National Committee on Radiation Protection (1956): "Safe Handling of Cadavers Containing Radioactive Isotopes." U.S. Department of Commerce, National Bureau of Standards Handbook 56. Washington D.C.: U.S. Department of Commerce.

Olsen JH, Asnaes S (1986): Formaldehyde and the risk of squamous cell carcinoma of the sinonasal cavities. Br J Ind Med 43:769–774.

Olsen JH, Jensen SP, Hink M, Faurbo K, Breum NO, Jensen OM (1984): Occupational formaldehyde exposure and increased nasal cancer risk in man. Int J Cancer 34:639–644.

Roush GC, Walrath J, Stayner LT, Kaplan SA, Flannery JT, Blair A (1987): Nasopharyngeal cancer,

sinonasal cancer and occupations related to formaldehyde: A case-control study. JNCI 79:1221–1225.

Schottenfeld D, Fraumeni JF, Jr (1982): "Cancer Epidemiology and Prevention." New York: W.B. Saunders, Co.

Stayner LT, Elliott L, Blade L, Keenlyside R, Halperin W (1988): A retrospective cohort mortality study of workers exposed to formaldehyde in the garment industry. Am J Ind Med 13:667–681.

Stroup NE, Blair A, Erikson GE (1986): Brain cancer and other causes of death in anatomists. JNCI 77:1217–1224.

Tobe M, Kaneko T, Uchida Y, Kamata E, Ogawa Y, Ikeda Y, Saito M (1985): "Studies on the Inhalation Toxicity of Formaldehyde." Report of the National Sanitary and Medical Laboratory Service. Tokyo: Toxicity Department of the Organism Safety Research Center, p 94.

U.S. National Center for Health Statistics (1967): "Eighth Revision International Classification of Diseases." ICDA Volume 1. Public Health Service Publication No. 1693. Washington, D.C.: U.S. Government Printing Office.

Vaughn TL, Strader C, Davis S, Daling JR (1986a): Formaldehyde and cancers of the pharynx, sinus and nasal cavity. I. Occupational exposures. Int J Cancer 38:677–683.

Vaughn TL, Strader C, Davis S, Daling JR (1986b): Formaldehyde and cancers of the pharynx, sinus and nasal cavity. II. Residential exposures. Int J Cancer 38:685–688.

Walker SD (1986): Cause-deleted mortality and proportional mortality analysis and the healthy worker effect. Stat Med 5:61–71.

Walrath J, Fraumeni JF, Jr (1983): Mortality patterns among embalmers. Int J Cancer 31:407–411.

Walrath J, Fraumeni JF, Jr (1984): Cancer and other causes of death among embalmers. Cancer Res 44:4638–4641.

Williams TM, Levine RJ, Blunden PB (1984): Exposure of embalmers to formaldehyde and other chemicals. Am Ind Hyg Assoc J 45:172–176.