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Evaluation of Risks for Non-Hodgkin's Lymphoma by Occupation and Industry Exposures From a Case-Control Study

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The etiology of non-Hodgkin's lymphoma (NHL) is not well understood. To develop hypotheses on causes of this tumor, data from a population-based case-control interview study of 1,867 white men (622 cases and 1,245 controls) in Iowa and Minnesota conducted during 1980–1983 were examined. Subjects, or their next of kin, were interviewed to obtain information on agricultural exposures, work history, medical conditions, and family history. This analysis focuses on risks of NHL by occupation, by industry, and by selected exposures. Although many comparisons were made, few significant associations were observed. Small numbers and limitations in exposure assessment, however, would tend to reduce opportunities to detect associations. The strongest finding was with various occupations that work in metals and metal products. The analysis by exposure estimates also uncovered a significant association with metals, but risks did not increase with estimated intensity of exposure. Slightly elevated risks were also noted among persons employed as painters and construction workers, agricultural and forestry workers, printers and typesetters, funeral directors and embalmers, and dry cleaners. Although the overall risks for benzene and other solvents were small, they increased slightly with level of assigned exposure. Although some associations may be due to chance, several of these occupations and industries have been linked to lymphoma in other investigations and deserve further attention.

Key words: occupational risk estimation, cancer, printers, dry cleaners, benzene, metal working, NHL, non-agricultural exposures, embalmers

INTRODUCTION

Despite rising incidence and mortality rates in the United States [Devesa et al., 1987; Pickle et al., 1987] and elsewhere [Davis et al., 1990], the etiology of non-

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Hodgkin's lymphoma (NHL) is poorly understood [Greene, 1982]. Immunodeficiency syndromes, including human immunodeficiency virus (HIV) infections [Gail et al., 1991], and therapeutic immunosuppression [Filipovich et al., 1980], are clearly linked with NHL. Associations have been reported with several environmental factors, including radiation, drugs, infectious agents, and chemicals [Greene, 1982]. NHL has also been associated with employment in various occupations and industries, including farming [Blair and Zahm, 1991], particularly farmers exposed to herbicides [Hoar et al., 1986; Zahm et al., 1990; Woods et al., 1987]; the rubber, plastics, and synthetics industry [Schumacher and Delzell, 1988; Downes et al., 1987]; road transport workers [Balarajan, 1983]; plumbers [Doln et al., 1983; Cantor et al., 1986]; printing workers [Greene et al., 1979; Zoloth et al., 1986]; foundries [Giles et al., 1984]; chemists [Li et al., 1969; Olin, 1978]; and funeral directors and embalmers [Linos et al., 1989; Hayes et al., 1990]. To evaluate further the role that occupational exposures may play and to develop new clues to the etiology of this poorly understood cancer, we analyzed data from a case-control interview study among white men in Iowa and Minnesota, 1980–1983.

MATERIALS AND METHODS

The data for this analysis are derived from a population-based case-control interview study primarily designed to evaluate cancer risks from agricultural exposures [Brown et al., 1990], but information on other potential risk factors, including occupation, was obtained. In Iowa, cases consisted of white men with NHL reported to the Iowa State Health Registry from March 1981 to October 1983 and in Minnesota, cases were white men diagnosed between October 1980 and September 1982 from a surveillance network of hospitals. Cases and controls residing in the cities of St. Paul, Duluth, Minneapolis, and Rochester were excluded because agricultural exposures were the primary focus of this study. Coverage was quite complete since participating hospitals contained 97% of the available hospital beds in the state. Pathologic specimens for the cases ascertained were reviewed by a panel of pathologists and assigned to subtypes according to the Working Formulation [Dick et al., 1987]. Of the 715 cases eligible following pathology review, 622 (87%) were interviewed (438 cases were directly interviewed and 184 interviews were with next of kin). Of the 72 cases not confirmed as NHL, 26 were diagnosed as leukemia and 46 were other conditions.

White men without hematopoietic or lymphatic malignancy were selected as controls. Controls for living cases under age 65 at diagnosis were selected by random digit dialing [Wakesburg, 1978]. Controls for living cases age 65 and over were selected from the computerized Medicare files of the Health Care Finance Administration. Controls for deceased cases, regardless of age, were selected from listings of deaths from state vital records. All controls were frequency matched by state, age (5-year categories), and by year of death for deceased cases. Of the 1,245 controls (approximately a 2:1 match with cases), 820 interviews were directly with subjects and 425 were with next of kin. Participation rates were 77% from random digit dialing (telephone screener response rate (87.5%) X interview response rate (88%)), 79% from Medicare, and 77% from death certificates.

In-person interviews of all cases and controls, or surrogate respondents, were conducted by trained interviewers using a structured questionnaire requiring approx-

imately one hour to administer. Interviews of cases and controls took place simultaneously. Information was sought on sociodemographic characteristics; agricultural exposures, including types of crops and animals raised and pesticides used; exposures to chemicals through hobbies; residential history; medical history; familial history of cancer; and a detailed occupational history. In the occupational section of the questionnaire, information was obtained on: all jobs held one year or more since the age of 18; the industry and name of the employer; the products that were produced; the actual occupational title; and the duties of the employee. Job titles and industries obtained from the occupational history were subsequently coded according to the Dictionary of Occupational Titles (DOT) (U.S. Department of Labor, 1977) and Standard Industrial Classification (SIC) (Office of Management and Budget, 1979) codes.

A job–exposure matrix for selected factors was developed for each DOT/SIC combination occurring in the work histories. An industrial hygienist (PAS) assessed the potential for exposures based on her understanding of exposures likely to be associated with the jobs and industries reported by subjects or next of kin. Assessments were made without knowledge of the subject's case-control status, or the results of the analyses of the data by occupation and industry codes. She evaluated the probability and intensity of exposure to various substances putatively related to NHL including benzene, other organic solvents, oils (which includes petroleum, cutting, cooling, and lubricating oils) and grease, motor exhausts, paints, electromagnetic radiation, metals (which included mining and refining ores, foundries, and producing and repairing metal products), wood dust, asbestos, formaldehyde, asphalt and other tar products, fresh meats, and solder fumes. These assessments were based on nonfarming jobs. Pesticides were not included in the matrix because they were specifically covered in a separate, extensive section on agriculture in the questionnaire and are the subject of another report [Cantor et al., 1992]. Subjects employed only as farmers were not included, leaving 546 cases and 1,087 controls available for the exposure analyses. Exposures for each job/industry combination were scored on a 4-point scale for probability of exposure and a 3-point scale for intensity of exposure. Probability and intensity exposure assessments considered the years in which each job/industry combination was held. For example, formaldehyde was considered an exposure in the plywood industry only after 1935 because it was not used prior to that date in the industry. The estimated formaldehyde level in the plywood industry was reduced after 1977 because of enhanced industry efforts to control ambient air levels.

Odds ratios (OR) and 95% confidence intervals (CI) were calculated using polychotomous unconditional logistic models (Cox, 1970; Dixon, 1983) from a computer program developed by the Epidemiology and Biostatistics Program of the National Cancer Institute. Odds ratios were calculated for all 2-digit and 3-digit DOT (151 comparisons) and SIC codes (155 comparisons) and for specific exposures from the job exposure matrix. Other factors in these data associated with NHL included in the model to control for confounding were as follows: age (<45, 45–64, >65); state of residence (Iowa or Minnesota); direct or surrogate respondent; agricultural use of pesticides (ever, never); postsecondary education (yes, no); use of hair dyes (ever, never); parent, sibling, or child with malignant lymphoproliferative diseases (yes, no); and ever used tobacco (yes, no). Analyses were performed for three major histologic types of NHL (follicular (combines small cleaved cell, mixed cell, and large cell follicular cases), diffuse (combines small cleaved cell, mixed cell, and large

TABLE I. Statistically Significant Associations Between Non-Hodgkin's Lymphoma and Employment by Industry and Occupation

Title and (Code)	No. of exposed ca/co	OR[a]	95% CI
Industry			
Special indust. machinery (355)	7/1	9.6	1.1–80.6
Real estate (651)	8/4	3.9	1.01–14.8
Personal services (72)	31/31	1.9	1.1–3.2
Occupation			
No significant associations observed			

[a]OR adjusted for age, state, smoking, family history of malignant lymphoproliferative diseases, agricultural exposure to pesticides, use of hair dyes, and direct or surrogate respondent.

cell diffuse cases) and other (combines small lymphocytic, large cell immunoblastic, lymphoblastic, small noncleaved, other and unclassified NHL)) for selected occupations, industries, and exposures (generally for those showing overall excesses, where numbers permitted). Exposure-response relationships were evaluated by examining the risk of NHL, or NHL subtypes, by duration of employment in various SIC and DOT categories, or by intensity, or probability of exposure to specific chemicals. Unexposed cases and controls were those not employed in the particular occupation, industry, or lacking the exposure being evaluated.

RESULTS

Table I presents industries and occupations by 2-digit or by 3-digit SIC and DOT codes with statistically significant relative risks for NHL. The largest risk occurred among workers from the industry producing special industrial machinery (OR = 9.6). Other industrial categories with significantly elevated risks were real estate (OR = 3.9), and personal services (OR = 1.9). No statistically significant associations were found with 2-digit or 3-digit occupational codes.

Of the approximately 150 occupation and 150 industrial categories evaluated, Table II displays those with more than 2 exposed cases where ORs for NHL were 1.5 or greater, but where the ORs were not statistically significant. For industries, ORs of 3.0 or more occurred among persons working in forestry, metalworking machinery equipment, miscellaneous transportation equipment, air transportation certified carriers, furniture and home furnishing sales, retail bakeries, camps and trailer parks, and physicians' offices. Occupational titles with ORs of 3.0 or greater for NHL occurred for budget and management, domestic service, household and related work, pouring and casting, miscellaneous metalworking, paving occupations, and concrete mixing truck drivers (Table III).

The risk of NHL increased with duration of employment for a few jobs and industries (no table). ORs and 95% CI by duration of employment (<10 years and >10 years) by selected occupations were finance, insurance, and real estate OR = 0.9 (95% CI = 0.2–4.8) and OR = 3.7 (95% CI = 1.4–9.5); computing and accounting OR = 1.1 (95% CI = 0.6–2.0) and OR = 3.8 (95% CI = 1.7–8.4); janitors OR = 1.2 (95% CI = 0.6–2.5) and OR = 1.7 (95% CI = 0.7–4.2); painting, plastering, and cementing OR = 0.6 (95% CI = 0.1–2.0) and OR = 2.7 (95% CI = 1.1–6.6); and con-

TABLE II. Nonsignificant Associations (OR >1.5) Between Non-Hodgkin's Lymphoma and Employment by Industry (Based on 2 or More Exposed Cases)

Title and (Code)	No. of exposed ca/co	OR[a]	95% CI
Agricultural production (01)	11/10	2.3	0.9–5.8
Forestry (08)	3/1	6.2	0.6–59.2
Painting/paper hanging (172)	16/16	1.9	0.9–3.8
Masonry, tile setting (174)	9/16	2.6	0.9–3.8
Textile mill products (22)	4/4	2.3	0.6–9.4
Apparel (23)	7/6	2.4	0.7–8.0
Paper/paperboard (264)	8/8	1.6	0.6–4.2
Misc. chemical products (289)	5/4	2.2	0.6–8.5
Petroleum refining (29)	5/5	1.6	0.5–5.8
Tires and inner tubes (301)	5/4	2.5	0.6–10.6
Concrete/gypsum/plaster (327)	7/9	1.5	0.5–4.1
Cut stone/stone products (328)	3/1	2.6	0.2–29.0
Fabricated metal (34)	54/89	1.4	0.96–2.0
Metalworking machinery (354)	8/4	3.0	0.9–10.2
Aircraft parts (372)	4/3	1.9	0.9–3.8
Misc. transportation equip (379)	4/3	3.8	0.6–18.6
Toys and sporting goods (394)	4/2	2.5	0.4–15.1
Transportation by air (45)	7/6	1.8	0.6–5.5
Air transport (certif.) (451)	4/2	3.1	0.6–16.9
Furniture sales (502)	3/1	4.9	0.5–47.2
Lumber dealers (521)	19/20	1.6	0.8–3.1
Retail bakeries (546)	3/1	4.7	0.5–46.3
Life insurance (631)	6/8	1.5	0.5–4.6
Insurance agents (641)	11/10	1.6	0.7–4.0
Camps and trailer parks (703)	3/1	5.5	0.6–53.4
Laundry/garment services (721)	16/14	2.0	0.97–4.3
Barbershops (724)	6/8	2.7	0.9–8.7
Funeral service (726)	6/4	2.1	0.5–7.9
Services to dwellings (734)	4/3	1.6	0.4–7.4
Theatrical producers (792)	4/4	1.6	0.4–6.6
Offices of physicians (801)	5/3	3.4	0.8–14.4
Labor unions and organiz. (863)	3/2	2.3	0.4–14.2

[a]OR adjusted for age, state, smoking, family history of malignant lymphoproliferative diseases, agricultural exposure to pesticides, use of hair dyes, and direct or surrogate respondent.

struction and maintenance painters OR = 0.5 (95% CI = 0.1–2.3) and OR = 2.3 (95% CI = 0.8–6.5). ORs also increased with duration of employment in the printing and publishing industry OR = 0.5 (95% CI = 0.2–1.3) and OR = 2.5 (95% CI = 1.1–5.7) and the fabricated metal products industry OR = 1.4 (95% CI = 0.6–3.2) and OR = 2.3 (95% CI = 0.7–6.9).

Risks by specific exposures are presented in Table IV. No OR was greater than 1.4 and only exposure to metals and metal products with an OR of 1.3 (95% CI = 1.0–1.6) was statistically significant. Risk of NHL was also evaluated by intensity or probability of exposure to these substances. Patterns by probability of exposure and cumulative exposure were similar to those by intensity and are not presented. The ORs were slightly larger in the higher intensity category than in the lower category for benzene (ORs of 1.5 and 1.1, respectively), other organic solvents

TABLE III. Nonsignificant Associations (OR >1.5) Between Non-Hodgkin's Lymphoma and Employment by Occupation (Based on 2 or More Exposed Cases)

Title and (Code)	No. of exposed ca/co	OR[a]	95% CI
Occupations in life sciences (04)	6/5	1.6	0.5–5.4
Budget and management (161)	3/1	4.9	0.5–47.7
Finance, real estate (186)	16/11	1.9	0.9–4.2
Accounting (216)	6/3	2.9	0.7–11.8
Computing records (219)	3/2	2.3	0.4–13.9
Accommodation clerks (238)	3/2	2.2	0.4–13.2
Sporting/hobby sales (277)	5/5	1.9	0.5–7.1
Domestic service (30)	4/2	4.6	0.5–41.6
Household and related work (301)	4/1	4.6	0.5–41.6
Chefs and cooks (313)	13/11	1.5	0.7–3.4
Barbering, cosmetology (33)	7/10	2.1	0.7–5.9
Misc. personal services (359)	4/2	2.1	0.4–11.5
Apparel and furnishing (36)	9/11	1.8	0.7–4.3
Police officers (376)	4/3	1.5	0.3–6.8
Plant life (408)	6/6	1.5	0.3–3.8
Forest conservation (452)	4/5	1.8	0.5–6.7
Occupations in processing (50)	9/8	1.5	0.6–4.0
Pouring and casting (514)	3/1	3.2	0.3–32.6
Cooking and baking (526)	6/9	1.6	0.5–4.9
Toolmakers (601)	8/5	2.6	0.8–8.8
Misc. metal working (619)	3/3	3.5	0.4–34.2
General industry workers (630)	7/7	1.5	0.5–4.7
Typesetters (650)	3/1	2.7	0.3–26.8
Printing press occupations (651)	6/5	1.5	0.4–5.1
Machine trades, NEC (69)	5/8	1.5	0.4–5.0
Metal unit assignment (706)	8/7	1.6	0.5–4.7
Body workers, trans. equip. (807)	5/4	1.5	0.4–5.6
Paving occupations (853)	3/2	3.4	0.6–20.8
Strutural maintenance (891)	3/2	2.0	0.3–12.0
Concrete-mixing truck dr. (900)	4/1	3.7	0.4–36.2

[a]OR adjusted for age, state, smoking, family history of malignant lymphoproliferative diseases, agricultural exposure to pesticides, use of hair dyes, and direct or surrogate respondent.

(ORs of 1.4 and 1.1), and live plants, other than in agriculture (ORs of 1.3 and OR = 1.0) (Table V).

Although small numbers made comparisons unstable, elevations in risk by occupation, industry, or exposure tended to occur for follicular or diffuse lymphoma rather than the "other NHL" category. Diffuse NHL was significantly associated with exposure to paints (OR = 1.5, 95% CI = 1.1–2.3) and employment in personal services (SIC 72) (OR = 2.1, 95% CI = 1.0–4.5) or medical professions (OR = 2.6, 95% CI = 1.3–5.2). Follicular NHL was significantly associated with metal exposures (OR = 1.6, 95% CI = 1.1–2.2), and employment in personal services (SIC 72) (OR = 3.6, 95% CI = 1.7–7.5), or as cooks or chefs (OR = 3.1, 95% CI = 1.1–8.6). Risk of follicular and diffuse NHL rose with increased intensity of exposure to benzene; for diffuse NHL, risk rose with solvents other than benzene and formalde-

TABLE IV. Odds Ratios for Non-Hodgkin's Lymphoma by Selected Potential Exposures

Exposure	OR[a]	#ca/co	95% CI
Benzene	1.1	153/301	0.9–1.4
Solvents other than benzene	1.1	359/686	0.9–1.4
Formaldehyde	1.2	84/137	0.9–1.7
Paints	1.1	116/221	0.9–1.5
Other chemicals	1.1	341/653	0.9–1.4
Oils and greases	1.1	280/517	0.9–1.4
Gasoline and diesel exhausts	1.0	265/511	0.8–1.3
Asphalt and creosote	1.0	53/105	0.7–1.5
Cooking oils	1.1	45/82	0.7–1.6
Ionizing radiation	1.4	20/34	0.8–2.5
Electromagnetic radiation	0.9	121/272	0.7–1.1
Metals	1.3	221/381	1.01–1.6
Solder	0.8	114/263	0.6–1.1
Wood dust	0.9	88/175	0.7–1.2
Asbestos	1.2	202/360	0.99–1.6
Paper dust	1.3	20/30	0.7–2.3
Medical profession	1.3	24/33	0.8–2.4
Jobs relating to children	1.0	29/57	0.6–1.6
Live cattle	0.9	93/207	0.7–1.2
Any meats	0.8	92/227	0.6–1.0
Live plants, other than agriculture	1.0	121/235	0.8–1.3

[a]OR adjusted for age, state, smoking, family history of malignant lymphoproliferative diseases, agricultural exposure to pesticides, use of hair dyes, and direct or surrogate respondent.

hyde; and for follicular NHL, risk rose with oils and greases (Table VI). Neither diffuse nor follicular showed much of an association with intensity of exposure to asbestos.

DISCUSSION

Data from a case-control study of NHL were analyzed to generate clues regarding the role of occupational exposures in the etiology of this tumor. Many comparisons were made by occupation (>150 categories), by industry (>150 categories) and by exposure (27 different categories); some significant associations would be expected simply on the basis of chance. Evaluation by duration or intensity of potential exposures, however, tends to counter this limitation. We observed relatively few significant associations. The small number of exposed subjects in most occupational or industrial categories, however, is a serious limitation. Analyses by exposure, which aggregate workers from different occupations or industries, yield larger numbers of exposed subjects, but with the limited exposure information available from the interview and the inability to visit places of employment it is impossible to avoid nondifferential misclassification by exposure. Limitations in exposure assessment would tend to decrease the probability of detecting underlying associations [Checkoway et al., 1989].

Although associations with employment in particular industries or occupations do not necessarily identify individual occupational exposures, they may point to combinations of exposures which can be evaluated in future investigations. We found several associations of particular interest. Significantly increased risks were seen

TABLE V. Odds Ratios for Non-Hodgkin's Lymphoma by Intensity of Potential Exposure to Selected Factors

	Lower intensity			Higher intensity		
Exposure	OR[a]	#ca/co	95% CI	OR[a]	#ca/co	95% CI
Benzene	1.1	141/283	0.8–1.4	1.5	12/18	0.7–3.1
Solvents other than benzene	1.1	334/648	0.8–1.4	1.4	25/38	0.8–2.5
Formaldehyde	1.2	78/128	0.9–1.7	1.3	6/9	0.5–3.8
Paints	1.1	107/204	0.9–1.5	1.1	9/17	0.5–2.6
Oils and greases	1.1	168/328	0.8–1.4	1.2	112/189	0.9–1.7
Gasoline and diesel exhausts	1.0	230/442	0.8–1.2	1.1	35/69	0.7–1.7
Asphalt and creosote	1.0	49/97	0.7–1.5	1.1	4/8	0.3–4.0
Cooking oils	1.5	37/53	0.9–2.3	0.4	8/29	0.2–1.0
Electromagnetic radiation	0.9	105/228	0.7–1.2	0.7	16/44	0.4–1.3
Metals	1.3	215/362	1.03–1.6	0.7	6/19	0.3–1.8
Solder	0.8	114/260	0.6–1.1	—	0/3	—
Wood dust	0.9	88/173	0.7–1.2	—	0/2	—
Asbestos	1.3	181/313	0.99–1.6	1.1	21/47	0.6–1.9
Medical prof.	1.8	20/19	0.9–3.6	0.6	4/14	0.2–2.0
Live cattle	0.9	77/165	0.7–1.2	0.7	16/42	0.4–1.3
Any meats	0.9	23/52	0.5–1.5	0.7	16/45	0.4–1.2
Live plants, other than agriculture	1.0	99/201	0.7–1.3	1.3	22/34	0.7–2.3

[a]OR adjusted for age, state, smoking, family history of malignant lymphoproliferative diseases, agricultural exposure to pesticides, use of hair dyes, and direct or surrogate respondent.

among metalworking machinery industries; and nonsignificant excesses were observed in other metalworking and manufacturing categories including fabricated metal, transportation equipment, aircraft parts, pouring and casting, toolmakers, miscellaneous metal working, and metal unit assignments. In these jobs, workers may come into close contact with metals and various organic solvents which may be associated with the development of NHL. Exposure to metals from the job exposure matrix was also significantly associated with the risk of NHL, particularly for follicular NHL, but the greater risk occurred among those exposed at lower levels. Several metals, i.e., arsenic, chromium, cadmium, and nickel, are carcinogenic in animals or humans, but lymphoma is not the type of cancer usually observed [IARC, 1987]. NHL has been previously associated with exposure to metals in various occupations in Italy [La Vecchia et al., 1989] and among foundry workers in Tasmania [Giles et al., 1984].

An association was found between NHL (for both diffuse and follicular histologic types) and employment in laundry and garment cleaning services. An excess of lymphoma has been previously reported in a cohort of dry cleaners [Blair et al., 1990]. Several solvents are carcinogenic in animals, and benzene and tetrachloroethylene have produced lymphatic and hematopoietic tumors [IARC, 1987]. From the job–exposure matrix, we found that risks of NHL rose with level of exposure to benzene and other solvents. NHL was associated with several organic solvents in a study of aircraft maintenance workers [Spirtas et al., 1991]. The report of clonal chromosome aberrations among persons with NHL who have had exposure to organic solvents indicates that these chemicals may damage genetic material in humans [Brandt et al., 1989].

Excesses among occupations involved in transportation, i.e., concrete mixing

TABLE VI. Odds Ratios for Histologic Types of Non-Hodgkin's Lymphoma by Intensity of Potential Exposure to Selected Factors

	Lower intensity			Higher intensity		
Exposure	OR[a]	#ca/co	95% CI	OR[a]	#ca/co	95% CI
Benzene						
Follicular	1.3	53/283	0.9–1.9	1.9	5/18	0.7–5.3
Diffuse	1.2	45/283	0.8–1.8	1.8	4/18	0.6–5.4
Other	0.8	43/283	0.5–1.2	0.9	3/18	0.3–3.1
Solvents other than benzene						
Follicular	1.4	116/648	0.9–2.0	1.1	6/38	0.4–2.7
Diffuse	1.0	98/648	0.7–1.5	2.4	12/38	1.2–5.0
Other	1.0	120/648	0.7–1.4	1.1	7/38	0.4–2.5
Formaldehyde						
Follicular	1.4	27/128	0.9–2.2	0.6	1/9	0.1–5.1
Diffuse	1.3	27/128	0.8–2.2	2.3	3/9	0.6–8.6
Other	1.0	24/128	0.6–1.6	1.2	2/9	0.3–5.8
Oils and greases						
Follicular	1.2	51/328	0.8–1.8	2.0	52/189	1.3–3.1
Diffuse	0.9	49/328	0.6–1.4	0.8	24/189	0.6–1.4
Other	1.1	68/328	0.8–1.6	1.0	36/189	0.7–1.6
Asbestos						
Follicular	1.6	67/313	1.1–2.3	1.1	7/47	0.5–2.6
Diffuse	1.2	50/313	0.8–1.7	1.4	8/47	0.6–3.2
Other	1.1	64/313	0.8–1.5	0.8	2/47	0.3–1.9

[a]OR adjusted for age, state, smoking, family history of malignant lymphoproliferative diseases, agricultural exposure to pesticides, use of hair dyes, and direct or surrogate respondent.

truck drivers and air transportation workers, may point to a problem with engine exhausts, but no excesses were observed among truckers or other drivers. Results from the exposure analysis, also, do not support an overall association with engine exhausts. An excess of NHL has previously been reported among persons employed in road transport [Balarajan, 1983] and among automobile mechanics [Schwartz, 1987]. The specific agents that could be involved have not been identified, but diesel fuel has been associated with NHL in humans [Wigle et al., 1990] and diesel exhausts cause lymphomas in rats [Iwai et al., 1987].

Others have reported increased risk of NHL among persons employed in the building trades [Ng, 1988], such as painters [Schumacher and Delzell, 1988] and carpenters [Brownson and Reif, 1988; Persson et al., 1989]. We found nonsignificant excesses among those employed in painting and plastering, structural maintenance, masonry and tile setting, and concrete, gypsum, and plastering. Risks increased with duration of employment as painters and plasterers.

Nonsignificant increases occurred among workers in forestry, plant life, and agricultural production. These occupations may share a common exposure to pesticides. NHL has been associated with agricultural workers in several countries [Blair and Zahm, 1991], particularly with the use of herbicides [Hoar et al., 1986; Zahm et al., 1990; Woods et al., 1987; Persson et al., 1989; Hardell et al., 1981]. Cantor et al. [1992] has evaluated risks of NHL from pesticide use among farmers in this study.

We observed nonsignificant excesses of NHL among those employed as cooks

and chefs in restaurants and hotels and retail bakeries and among cooks and bakers not otherwise classified. A significant excess occurred for follicular NHL among cooks and chefs.

Polynuclear aromatic compounds and heterocyclic amines are carcinogens that arise in cooking of foods and have been found in most human tissues including lymphocytes [IARC, 1983]. Information, however, is not available regarding exposures by inhalation to these substances during cooking and baking. From the job–exposure matrix, cooking oils were not related to NHL. We are not aware of other reports of lymphoma in these occupations, but NHL has been associated with employment in the food industry in a geographic mortality study [Cantor and Fraumeni, 1980].

Typesetters and printing press operators had elevated risks similar to other reports regarding lymphatic and hematopoietic cancer in the printing industry [Greene et al., 1979; Zoloth et al., 1986]. The risk of NHL increased with duration of employment in this industry.

Several white-collar occupations experienced increased risks, including finance and real estate managers, budget and management system analysts, accounting and statistical clerks, accommodation clerks, and people in computing and accounting records. These associations would not seem to suggest occupational exposures, but may reflect diagnostic factors due to access to better health care programs than available in other occupations.

In summary, this evaluation does not indicate that industrial exposures are a major contributor to the etiology of NHL, yet a few associations deserve further evaluation. Interpretation is difficult because limitations in exposure assessment would tend to diminish relative risks and some associations may be chance findings. The strongest finding was of elevated risks among workers in various metal-related occupations which may point to a role for solvents, cutting oils, and metal fumes. Exposure to metals in various occupations was also associated with NHL from the job exposure matrix, although risk did not rise with assigned level of exposure. Risk of NHL rose slightly with increasing level of exposure to benzene and to other solvents. Excesses among painters and other construction workers, agriculture and forestry workers, and printers and typesetters, funeral directors, and dry cleaners also deserve further evaluation.

REFERENCES

Balarajan R (1983): Malignant lymphoma in road transport workers. J Epidemiol Community Health 37:279–280.

Blair A, Stewart PA, Tolbert PE, Grauman D, Moran FX, Vaught J, Rayner J (1990): Cancer and other causes of death among a cohort of dry cleaners. Br J Ind Med 47:162–168.

Blair A, Zahm SH (1991): Cancer among farmers. In Cordes DH, Rea DF (eds): "State of the Art Reviews—Health Hazards of Farming." Philadelphia: Hanley and Belfus, pp 335–354.

Brandt L, Kristoffersson U, Olsson H, Mitelman F (1989): Relation between occupational exposure to organic solvents and chromosome aberrations in non-Hodgkin's lymphoma. Eur J Haematol 42: 298–302.

Brown LM, Blair A, Gibson R, Everett GD, Cantor KP, Schuman LM, Burmeister LF, Van Lier SF, Dick F (1990): Pesticides exposures and other agricultural risk factors for leukemia among men in Iowa and Minnesota. Cancer Res 50:6585–6591.

Brownson RC, Reif TS (1988): A cancer registry-based study of occupation risk for lymphoma, multiple myeloma and leukemia. Int J Epidemiol 17:27–32.

Cantor KP, Fraumeni JF Jr (1980): Distribution of non-Hodgkin's lymphoma in the United States between 1950 and 1975. Cancer Res 40:2645–2652.

Cantor KP, Sontag JM, Heid MF (1986): Patterns of mortality among plumbers and pipefitters. Am J Ind Med 10:73–79.

Cantor KP, Blair A, Everett G, Gibson R, Burmeister LF, Brown LM, Schuman L, Dick FR (1992): Pesticides and other agricultural risk factors for non-Hodgkin's lymphoma among men in Iowa and Minnesota. Cancer Res 52:2447–2455.

Checkoway H, Pearce NE, Crawford-Brown DJ (1989): "Research Methods in Occupational Epidemiology." New York: Oxford University Press.

Cox DR (1970): "The Analysis of Binary Data." London: Methuen.

Davis DL, Hoel D, Fox J, Lopez A (1990): International trends in cancer mortality in France, West Germany, Italy, Japan, England and Wales, and the USA. Lancet 2:474–481.

Devesa SS, Silverman DT, Young JL Jr, Pollack ES, Brown CC, Horm JW, Percy CL, Myers MH, McKay FW, Fraumeni JF Jr (1987): Cancer incidence and mortality trends among whites in the United States, 1947–84. JNCI 79:701–770.

Dick F, Van Lier S, Banks P, Frizzera G, Witrak G, Gibson R, Everett G, Schuman L, Isacson P, O'Conor G, Cantor K, Blattner W, Blair A (1987): The use of the working formulation for non-Hodgkin's lymphoma in epidemiologic studies: agreement between reported diagnoses and a panel of experienced pathologists. JNCI 78:1137–1144.

Dixon WJ (1983): "BMDP Statistical Software." Berkeley: University of California Press.

Doln BP, Levine AM, Dolan CD (1983): Small cleaved follicular center cell lymphoma: Seven cases in California plumbers. J Occup Med 25:613–615.

Downs TD, Crane MM, Kim KW (1987): Mortality among workers at a butadiene facility. Am J Ind Med 12:311–329.

Folipovich AH, Spector BD, Kersey J (1980): Immunodeficiency in humans as a risk factor in the development of malignancy. Prev Med 9:252–259.

Gail MH, Pluda JM, Rabkin CS, Biggar RJ, Goedert JJ, Horm J, Sondik EJ, Yarchoan R, Broder S (1991): Projections of the incidence of non-Hodgkin's lymphoma related to acquired immunodeficiency syndrome. JNCI 83:662–663.

Giles GG, Lickiss JN, Baikle MJ, Lowenthal RM Panton J (1984): Myeloproliferative and lymphoproliferative disorders in Tasmania, 1972–1980: Occupational and familial aspects. JNCI 72:1233–1240.

Greene MH (1982): Non-Hodgkin's lymphoma and *Mycosis fungoides*. In Schottenfeld D, Fraumeni JF Jr (eds): "Cancer Epidemiology and Prevention." Philadelphia: WB Saunders, pp 754–778.

Greene MH, Hoover RN, Eck RL, Fraumeni JR Jr (1979): Cancer mortality among printing plant workers. Environ Res 20:66–73.

Hardell L, Eriksson M, Lenner P, Lundgren E (1981): Malignant lymphoma and exposure to chemicals, especially organic solvents, chlorophenols and phenoxy acids: A case-control study. Br J Cancer 43:169–176.

Hayes RB, Blair A, Stewart PA, Herrick RF, Mahar H (1990): Mortality of U.S. Embalmers and funeral directors. Am J Ind Med 18:641–652.

Hoar SK, Blair A, Holmes FF, Boysen CD, Robel RJ, Hoover RN, Fraumeni JF Jr (1986): Agricultural herbicide use and risk of lymphoma and soft-tissue sarcoma. JAMA 256:1141–1147.

International Agency for Research on Cancer (1983): "IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Polynuclear Aromatic Compounds." Part 1: "Chemical, Environmental, and Experimental Data." Vol. 32. Lyons, France: IARC.

International Agency for Research on Cancer (1987): "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs." Vol. 1–42." Lyons, France: IARC.

Iwai K, Udagawa T, Yamagishi M, Yamada H (1987): Long-term inhalation studies of diesel exhaust on F344 SPF rats. Incidence of lung cancer and lymphoma. Dev Toxic Environ Sci 13:349–360.

La Vecchia C, Negri E, C'Avanzo B, Franceschi S (1989): Occupation and lymphoid neoplasms. Br J Cancer 60:385–388.

Li FP, Fraumeni JF, Mantel N, Miller RW (1969): Cancer mortality among chemists. JNCI 43:1159–1164.

Linos A, Blair A, Cantor KP, Burmeister L, VanLier S, Gibson RW, Schuman L, Everett G (1989): Leukemia and non-Hodgkin's lymphoma among embalmers and funeral directors. JNCI 82:66.

Ng, TP (1988): Occupational mortality in Hong Kong, 1979–1988. Int J Epidemiol 17:105–110.

Office of Management and Budget (1979): "Standard Industrial Classification Manual, 1979." Washington DC, US Government Printing Office.

Olin GR (1978): The hazards of a chemical laboratory environment: A study of the mortality of two cohorts of Swedish chemists. Am Ind Hyg Assoc J 39:557–562.

Persson B, Dahlander A, Fredriksson M, Brage HN, Ohlson C, Axelson O (1989): Malignant lymphomas and occupational exposures. Br J Ind Med 46:516–520.

Pickle LW, Mason TJ, Howard N, Hoover R, Fraumeni JF Jr (1987): "Atlas of U.S. Cancer Mortality Among Whites: 1950–1980." DHHS Publ. No. (NIH) 87-2900. Washington DC: US Department of Health and Human Services.

Schumacher MC, Delzell E (1988): A death-certificate, case-control study of non-Hodgkin's lymphoma and occupation in men in North Carolina. Am J Ind Med 13:317–330.

Schwartz E (1987): Proportionate mortality ratio analysis of automobile mechanics and gasoline service station workers in New Hampshire. Am J Ind Med 12:91–99.

Spirtas R, Stewart PA, Lee JS, Marano DE, Forbes CD, Grauman DJ, Pettigrew HM, Blair A, Hoover RN, Cohen JL (1991): Retrospective cohort mortality study of workers at an aircraft maintenance facility. I. Epidemiological results. Br J Ind Med 48:515–530.

U.S. Department of Labor Employment and Training Administration (1977): "Dictionary of Occupational Titles, 1977." Washington DC: US Department of Labor.

Wakesburg J (1978): Sampling methods for random digit dialing. J Am Stat Assoc 73:40–46.

Wigle DT, Semenciw RM, Wilkins K, Riedel D, Ritter L, Morrison HI, Mao Y (1990): Mortality study of Canadian male farm operators; Non-Hodgkin's lymphoma mortality and agricultural practices in Saskatchewan. JNCI 82:575–582.

Woods JS, Polissar L, Severson RK, Heuser LS, Kulander BG (1987): Soft tissue sarcoma and non-Hodgkin's lymphoma in relation to phenoxyherbicide and chlorinated phenol exposure in western Washington state. JNCI 78:899–910.

Zahm SH, Weisenburger DD, Babbitt PA, Saal RC, Vaught JB, Cantor KP, Blair A (1990): A case-control study of non-Hodgkin's lymphoma and the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) in eastern Nebraska. Epidemiology 1:349–356.

Zoloth SR, Michaels DM, Villalbi JR, Lacher M (1986): Patterns of mortality among commercial pressmen. JNCI 76:1047–1051.