Lung Cancer and Occupation in New Mexico

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ABSTRACT—The association between occupation and lung cancer risk was examined in a population-based, case-control study of 506 patients (333 males and 173 females) and 771 control (499 males and 272 females) subjects in New Mexico. A personal interview was used to obtain lifetime occupational and smoking histories and self-reported history of exposures to specific agents. High-risk jobs were identified in advance of data analysis and linked with industrial and occupational codes for hypothesis testing. For females, lung cancer risk was not associated with employment history, but power was limited. For males, elevated risks were found for the uranium mining industry (odds ratio (OR)=1.9; 95% confidence interval (CI)=0.8-4.9), underground miners (OR=2.1; 95% CI=1.1-3.7), painters (OR=2.7; 95% CI=0.8-8.9), and welders (OR=3.2; 95% CI=1.4-7.4). For self-reported exposure to any of 18 agents, only the OR for exposure to “other metals” was elevated. The population attributable risk in males was estimated as 14% for employment in any high-risk industry or occupation with an OR above 1 in this study.—JNCI 1987; 79:639-645.

Although cigarette smoking causes most cases of lung cancer in the United States, occupational agents also contribute to the development of lung cancer in smoking and nonsmoking workers (7). The evidence on occupational causes of lung cancer is derived primarily from studies of worker cohorts with specific exposures. The results of these studies, however, are frequently limited by lack of information on cigarette smoking and other confounding factors and by lack of a suitable unexposed control population. Because the subjects are most often selected from specific exposed populations, the cohort studies may not provide information about the risks of occupational exposures in the general population. In this regard, the extent to which occupation contributes to lung cancer has been controversial and not well characterized (2-4).

Population-based, case-control studies of occupation and lung cancer may provide information complementary to that from cohort studies. With the case-control approach, information can be collected concerning the entire work history and smoking habits; attributable risk can also be estimated from case-control data. However, the power of a population-based, case-control study in the likely range of effects may be limited by a low prevalence of occupational exposures and by sample size. Nevertheless, recent population-based, case-control studies have provided useful results on such exposures as the shipbuilding industry (5).

In New Mexico the descriptive epidemiology of lung cancer differs in the State’s Hispanic and non-Hispanic whites (6). We have conducted a population-based, case-control study of incident lung cancer cases in New Mexico, 1980–82, to address the differing occurrence of lung cancer in these 2 ethnic groups. The study questionnaire obtained a lifelong occupational history along with information on cigarette smoking, dietary intake of vitamin A, and other risk factors. We have used the occupational history to examine the risks of specific occupational exposures as a cause of lung cancer in New Mexico.

SUBJECTS AND METHODS

Study subjects.—Cases included Hispanic white and other white residents of New Mexico, ages 25 through 84 years, with primary lung cancer, other than bronchioloalveolar carcinoma, diagnosed between January 1, 1980, and December 31, 1982. Cases were identified by the New Mexico Tumor Registry, a member of the Surveillance, Epidemiology, and End Results Program of the National Cancer Institute (7). Since 1969, the New Mexico Tumor Registry has ascertained all cancer cases, other than non-melanoma skin cancers, in New Mexico’s residents. Controls were identified by screening randomly selected residential telephone numbers and, for persons ages 65 and older, from the Health Care Financing Administration’s roster of Medicare participants. The controls were frequency matched to cases for sex, ethnicity, and 10-year age category at a ratio of approximately 1.5 controls per case. Complete details concerning subject selection have been previously reported (8, 9).

This present report is based on data from 506 cases, 333 males and 173 females, and 771 controls, 499 males and 272 females, interviewed as of August 2, 1983. At

ABBREVIATIONS USED: CI = confidence interval; OR = odds ratio.

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that time the overall case interview rate with either the patient or a surrogate respondent was 89%, with patients' refusals or nonavailability of a respondent accounting for the remaining 11%. Next-of-kin provided interviews for 50% of the male cases and 43% of the female cases because the patient was too ill or deceased. For controls, the interview rate was 85%, and only 2% were provided by next-of-kin for both males and females.

Data collection.—Personal interviews were conducted by bilingual interviewers in the subjects' homes according to a standardized protocol. The questionnaires obtained a lifetime occupational history and a self-reported history of exposures to specific agents. For each job held for at least 6 months from age 12 years, questions were asked about the title of the position, duties performed, location and nature of employing industry, time at each job title, and full- or part-time status. The self-reported exposure history ascertained previous occupational exposure to 18 agents: asbestos, radiation, coal soot, tar or coke, nickel, chromium, arsenic, chloromethyl ether, polyurethane, formaldehyde, insecticides and pesticides, vegetable and animal dust, wood dust, leather dust, petroleum and petroleum products, and solvents. A detailed smoking history ascertained the number of cigarettes consumed daily, the number of years smoked, and the type of cigarettes smoked for each period of smoking, as well as the current cigarette smoking status.

Development of variables on occupational exposures.—Industries were coded according to the Standard Industrial Classification scheme (10), and occupations were coded according to the Standard Occupational Classification scheme (11). Both codes consist of 4 digits with each successive digit adding finer detail. The high prevalence of mining in New Mexico warranted modification of the Standard Occupational Classification coding scheme to identify specifically workers with underground experience. The occupational history was coded by a single person and reviewed by another.

To test hypotheses about specific high-risk jobs, one of us (M.L.L.) created a priori listings of the suspect occupations and industries (12). Development of this listing was a two-step process, involving literature review for implicated industries and occupations and a determination of the appropriate Standard Industrial Classification and Standard Occupational Classification codes associated with the job titles. The groupings provided in several summary reviews (13-16) were also used. Consistent reporting of excess risk in the literature was not a requirement for selection. Titles such as petroleum refining and chemical manufacturing were included, although published studies showed both increased and decreased risk for lung cancer.

Based on this classification process, the following industries were considered as potential risk factors for lung cancer: uranium mining, shipbuilding and ship repairing, nickel smelting and refining, petroleum refining, chemical manufacturing, construction, furniture making, printing, rubber manufacturing, asbestos products manufacturing, blast furnaces and steel works, and iron and steel foundries. Similarly, the following occupations were considered to be risk factors: underground miners, other underground workers, construction workers, painters, plumbers, shipyard workers, insulation workers, asphalt pavers, sheetmetal duct installers, locomotive engineers and foremen, foundrymen, coke oven workers, diesel engine mechanics, automobile mechanics, welders, woodworkers, and printers.

We next linked these industries and occupations to specific codes in the Standard Industrial Classification and Standard Occupational Classification. Initially, an attempt was made to match the occupational and industrial titles to codes. For some occupations, such as "coke oven workers," it was necessary to link occupation with the industry codes because the Standard Occupational Classification code alone was not sufficiently specific. In addition, it was necessary to group industrial and occupational codes when a job title was so broad that several codes could apply. For example, "woodworkers" were identified by constructing a group of job titles that probably share the duties and exposures of woodworkers.

For four agents—asbestos, wood dust, diesel exhaust, and formaldehyde—industries and occupations that we determined to have exposure were identified and grouped by Standard Industrial Classification and Standard Occupational Classification codes. The decisions concerning linkages of specific industries and occupations to specific exposures were based on literature review and consultation with local industrial hygienists. All jobs included in the lifetime occupational history were matched against this a priori listing. We recorded whether any job held during a lifetime was included on this listing and, if so, calculated the number of years of employment. For each subject, any employment in exposed jobs was noted, and the duration of potential exposure to each agent was calculated.

Data analysis.—We reviewed interviews that recorded less than 20 years of employment during the subject's lifetime. On the basis of this review, 4 male cases (3 non-Hispanic whites and 1 Hispanic white) and 2 controls (1 non-Hispanic white and 1 Hispanic white) were excluded from the analysis because more than 15 years of the employment history could not be provided by the respondent.

For analysis, the measure of employment experience was whether an individual was "ever employed" for at least 1 year in an industry or occupation. The "unexposed," or reference, group was defined as those subjects never employed in that particular industry or occupation. For calculating risk associated with suspect occupations and industries, an additional reference group was used: individuals never employed in any of the suspect high-risk industries or occupations. To identify new associations of lung cancer with industries and occupations not specified a priori, we examined risk for employment in any industry or occupation with at least 5 cases or controls. Initially, we used stratified analysis to quantify the association between occupation and lung cancer using the Mantel-Haenszel method (17). Because frequency matching was used to select controls, all models included appropriate adjustment for ethnic-
ity and age. The stratified analysis was done with programs prepared by Rothman and Boice (18). To control simultaneously for age, ethnicity, and smoking status, we then carried out the analysis using two multiple logistic regression models (19). For the first model, indicator variables were assigned for ever or never employment, non-Hispanic white or Hispanic ethnicity, age less than 65 years or 65 years and greater, and cigarette smoking status (never, ex-smoker, and current). The second model included variables to control more completely for cigarette smoking (20) and for level of carotene consumption (8). In addition to the indicator variables for age, ethnicity, cigarette smoking status, and employment, continuous variables were added for average number of cigarettes smoked daily and the duration of smoking, and indicator variables were added for the tertiles of carotene consumption. For those industries and occupations with elevated ORs, we calculated the population attributable risk estimate according to the method of Cole and MacMahon (21). Adjustment for possible confounding by smoking was accomplished by the maximum likelihood method proposed by Whittemore (22).

RESULTS

We first considered the occupational experience of females, exclusive of time spent as a housewife. Cases and controls had held an average of 2.8 and 2.5 unique full-time jobs, respectively. The duration of full-time employment was 15 years for cases and 14 years for controls. Hispanic female controls had not been employed in any of the high-risk jobs; in the non-Hispanic white controls, employment in a high-risk job was recorded for at least 5 controls for only 2 industries, construction and painting, and for no occupations. The ORs for employment in construction and painting were not sign.

The series of males for the present analyses included 333 cases and 499 controls (table 1). In the combined cases and controls, 83% of the Hispanics and 9% of the non-Hispanic whites were born in New Mexico. The cases and controls in both ethnic groups were comparable with regard to birthplace. The educational background of the Hispanic and non-Hispanic whites differed, with 6.8 and 12.2 mean years of schooling, respectively.

Among males, reported occupational experience was similar for controls and for the cases who gave their own employment histories (table 2). In the case series, the surrogate respondents reported fewer jobs and fewer years of employment than did the index cases. The extent of missing information was greater for the histories reported by the surrogate respondents. In the self-reported information for cases and controls, at least one occupation or one industry was missing for 1 and 2%, respectively; the surrogate-reported histories were missing for 6 and 10%, respectively.

We calculated ORs associated with jobs that involved the suspect industries and occupations and in which at least 5 controls reported employment (table 3). To minimize loss of subjects because of missing information on smoking or diet, tables 3–5 present the results of the logistic model with more limited smoking variables and without variables for carotene consumption. The findings were unchanged with the more complete model, but 39 subjects were dropped because of missing data. The ORs shown in table 3 were calculated with the subject never employed in the tested industry or occupation as the reference group. The results were unchanged when subjects never employed in any of the at-risk industries and occupations were the reference group.

Elevated ORs were found for the uranium industry and for underground miners, painters, and welders. The level of statistical significance varied with the analysis method, and estimates of the ORs did not change greatly with adjustment for cigarette smoking. The groupings based on presumed exposure to specific agents were not associated with increased risk. In the more complete model, the ORs were 2.8 (95% CI = 1.0–7.7) for welders, 2.3 (95% CI = 1.2–4.4) for underground miners, 2.4 (95% CI = 0.6–9.6) for construction painters, and 4.3 (95% CI = 1.6–11.0) for welders.

The elevated risks in welders and underground miners were further examined with stratification by type of industry (table 4). The reference group for underground miners was defined as subjects never employed as an underground miner or in the uranium mining industry. The reference group for welders was subjects never employed as a welder or in the shipbuilding industry.
Table 3.—ORs for employment in certain industries and occupations in a case-control study of lung cancer in New Mexico males, 1980-82

<table>
<thead>
<tr>
<th>Employment or exposure</th>
<th>Cases (n=332)</th>
<th>Controls (n=499)</th>
<th>OR*</th>
<th>Age and ethnicity adjusted OR</th>
<th>Age, ethnicity, and smoking adjusted (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uranium mining</td>
<td>12</td>
<td>9</td>
<td>2.1</td>
<td></td>
<td>1.9 (0.8-4.9)</td>
</tr>
<tr>
<td>Shipbuilding</td>
<td>15</td>
<td>19</td>
<td>1.1</td>
<td></td>
<td>1.0 (0.5-2.1)</td>
</tr>
<tr>
<td>Petroleum refining</td>
<td>4</td>
<td>9</td>
<td>0.6</td>
<td></td>
<td>0.6 (0.2-2.1)</td>
</tr>
<tr>
<td>Construction</td>
<td>74</td>
<td>124</td>
<td>0.9</td>
<td></td>
<td>0.8 (0.6-1.1)</td>
</tr>
<tr>
<td>Printing</td>
<td>11</td>
<td>17</td>
<td>1.1</td>
<td></td>
<td>0.8 (0.4-1.8)</td>
</tr>
<tr>
<td>Blast furnaces and steel mills</td>
<td>1</td>
<td>7</td>
<td>0.5</td>
<td></td>
<td>0.2 (0.0-1.7)</td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground miners</td>
<td>31</td>
<td>25</td>
<td>1.9</td>
<td></td>
<td>2.1 (1.1-3.7)</td>
</tr>
<tr>
<td>Construction workers</td>
<td>98</td>
<td>144</td>
<td>1.0</td>
<td></td>
<td>0.9 (0.7-1.3)</td>
</tr>
<tr>
<td>Painters</td>
<td>9</td>
<td>6</td>
<td>2.1</td>
<td></td>
<td>2.7 (0.8-8.9)</td>
</tr>
<tr>
<td>Plumbers</td>
<td>12</td>
<td>15</td>
<td>1.1</td>
<td></td>
<td>1.0 (0.5-2.3)</td>
</tr>
<tr>
<td>Paving equipment operators</td>
<td>7</td>
<td>6</td>
<td>1.7</td>
<td></td>
<td>1.6 (0.5-5.0)</td>
</tr>
<tr>
<td>Roofers</td>
<td>2</td>
<td>5</td>
<td>0.6</td>
<td></td>
<td>0.5 (0.1-2.7)</td>
</tr>
<tr>
<td>Engineers and firemen</td>
<td>2</td>
<td>6</td>
<td>0.8</td>
<td></td>
<td>0.6 (0.1-3.3)</td>
</tr>
<tr>
<td>Diesel engine mechanics</td>
<td>5</td>
<td>11</td>
<td>1.0</td>
<td></td>
<td>0.6 (0.2-2.0)</td>
</tr>
<tr>
<td>Auto mechanics</td>
<td>15</td>
<td>25</td>
<td>0.7</td>
<td></td>
<td>0.9 (0.5-1.9)</td>
</tr>
<tr>
<td>Welders</td>
<td>19</td>
<td>10</td>
<td>3.0</td>
<td></td>
<td>3.2 (1.4-7.4)</td>
</tr>
<tr>
<td>Woodworkers</td>
<td>10</td>
<td>20</td>
<td>0.7</td>
<td></td>
<td>0.8 (0.3-1.7)</td>
</tr>
<tr>
<td>Printers</td>
<td>5</td>
<td>7</td>
<td>1.2</td>
<td></td>
<td>0.8 (0.3-2.6)</td>
</tr>
<tr>
<td>Underground uranium miners</td>
<td>7</td>
<td>5</td>
<td>2.0</td>
<td></td>
<td>2.1 (0.6-7.2)</td>
</tr>
<tr>
<td>Shipyard workers</td>
<td>6</td>
<td>10</td>
<td>0.9</td>
<td></td>
<td>0.6 (0.2-1.8)</td>
</tr>
<tr>
<td>Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel exhaust fumes</td>
<td>7</td>
<td>17</td>
<td>0.9</td>
<td></td>
<td>0.6 (0.2-1.6)</td>
</tr>
<tr>
<td>Asbestos</td>
<td>40</td>
<td>51</td>
<td>1.0</td>
<td></td>
<td>1.1 (0.7-1.7)</td>
</tr>
<tr>
<td>Wood dust</td>
<td>10</td>
<td>20</td>
<td>0.7</td>
<td></td>
<td>0.8 (0.3-1.7)</td>
</tr>
</tbody>
</table>

* Risks are relative to never employed in that industry. ORs adjusted for age and ethnicity alone by stratified analysis. ORs adjusted for smoking in addition to age and ethnicity by the logistic model described in “Subjects and Methods.”

For welders, those without employment in the shipyard industry were at significantly increased risk for lung cancer. The OR for those with any shipyard welding experience was increased but not significantly, although subject numbers were small. In the miners the ORs were comparable for those with and without uranium mining experience.

To identify associations not hypothesized in advance between occupation and lung cancer, we calculated ORs for a posteriori groupings of industries and occupations (table 5). Consistent with the finding of elevated risk for the uranium mining industry, the OR for mining industry employment was elevated. Similarly, the OR for extractive occupations, which include underground miners, was elevated. The significantly elevated OR for employment in the motion picture industry could not be attributed to confounding by smoking.

We examined the risk associated with employment in any of the high-risk industries and occupations with an OR greater than 1. A total of 97 cases and 82 controls had been employed in any one industry or occupation of interest. The OR, adjusted for age, ethnicity, and smoking by logistic regression analysis, was significantly elevated (OR = 2.0; 95% CI = 1.5-2.7).

We also calculated the risk for lung cancer associated with self-reported, occupational exposure to any of the 18 agents listed previously. Only the risk associated with self-reported exposure to “other metals” was significantly elevated (age and ethnicity adjusted OR = 1.9; 95% CI = 1.4-2.6). Review of the interviews for 74 cases and 64 controls showed that most responses referred to mining, smelting, welding, and foundry occupations. Agents with elevated risks after adjustment for age and ethnicity but not for smoking were asbestos (OR = 1.5; 95% CI = 1.0-2.0), radiation (OR = 1.2; 95% CI = 0.9-1.9), and...
TABLE 5.—*ORS for employment in certain industries and occupations examined a posteriori in a case-control study of lung cancer in New Mexico, 1980-82

<table>
<thead>
<tr>
<th>Industry</th>
<th>Cases (n=333)</th>
<th>Controls (n=499)</th>
<th>ORa</th>
<th>Age and ethnicity adjusted</th>
<th>Age, ethnicity, and smoking adjusted (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating and drinking establishments</td>
<td>26</td>
<td>22</td>
<td>1.7</td>
<td>1.6 (0.8-2.9)</td>
<td></td>
</tr>
<tr>
<td>Mining industries</td>
<td>79</td>
<td>98</td>
<td>1.3</td>
<td>1.2 (0.8-1.7)</td>
<td></td>
</tr>
<tr>
<td>Motion pictures</td>
<td>8</td>
<td>4</td>
<td>3.2</td>
<td>5.0 (1.2-21.4)</td>
<td></td>
</tr>
<tr>
<td>Local and suburban passenger transportation</td>
<td>16</td>
<td>12</td>
<td>2.0</td>
<td>1.9 (0.8-4.5)</td>
<td></td>
</tr>
<tr>
<td>Occupation: extractiveb</td>
<td>43</td>
<td>41</td>
<td>1.3</td>
<td>1.6 (1.0-2.7)</td>
<td></td>
</tr>
</tbody>
</table>

a Risks are relative to never employed in that industry. ORs adjusted for age and ethnicity by stratified analysis. ORs adjusted for smoking in addition to age and ethnicity by the logistic model described in “Subjects and Methods.”
b Includes underground miners.

cloromethyl ether (OR=2.2; 95% CI=0.8-5.7), wood dusts (OR=1.5; 95% CI=1.1-2.0), and leather dusts (OR=1.7; 95% CI=0.7-4.3).

To estimate the proportion of lung cancer in this population due to occupational causes, we calculated the attributable risk for those suspect industries and occupations with ORs above unity (table 6). The proportion of lung cancer attributed to the uranium mining industry, underground miners, and underground uranium miners ranged from 1.0 to 4.3% for individual jobs. When all at-risk industries and occupations with ORs greater than 1 were combined, the proportion attributed to employment was 14%. Adjustment for cigarette smoking did not greatly change the attributable risk estimates.

DISCUSSION

We have conducted a population-based, case-control study directed at cigarette smoking, occupation, and other lung cancer risk factors in New Mexico. The population-based design limits selection bias and facilitates assessment of the overall importance of the risk factors of interest. Furthermore, information on cigarette smoking was collected in this study, and thus potential confounding of the effects of occupation by cigarette smoking could be controlled. The results of this study provide data on occupational risk factors for lung cancer in southwestern Hispanic and non-Hispanic white males, a population not previously examined.

Potential limitations of this study include information bias, selection bias, and inadequate statistical power for effects of a relevant magnitude. With regard to information bias, three sources must be considered: reliance on job title for determining exposure status, use of occupational histories obtained by interview and not further validated, and surrogate interviews for 47% of cases. While the study was population based and the case participation rate was high, selection bias could have resulted from differential participation by potential controls if the factors influencing participation, such as socioeconomic status, were associated with occupational exposure prevalence. Such bias cannot be excluded, but would not be anticipated to have strong effects because of the relatively high participation by controls.

In the context of this population-based, case-control study, use of job title was the only feasible approach for classifying exposure status. The reported industries and occupations spanned much of this century and diverse geographic locations. Grouping by exposure was thus generally not possible, and we did not use a job-exposure matrix as others have done (23, 24). We anticipate random misclassification from the approach that was used. Such random misclassification would bias the ORs toward the null (19).

The job histories covered the subjects’ entire lifetimes and included jobs in locations in New Mexico and elsewhere. Therefore, validation of the reported work histories was not possible. A Canadian study showed satisfactory validity for self-reported occupational information. Baumgarten et al. (25) found 82% concordance between a list of employers obtained by interview with subjects and the records of a government pension plan in Canada.

In any case-control study based on interview data, bias may be introduced if cases respond differently from controls. Our data do not indicate the presence of any
bias resulting from such differential reporting. Cases and controls reported similar numbers of jobs and duration of employment (table 2), and ORs were not uniformly elevated (table 3), as would be anticipated if recall bias were present. Of greater concern was the reliance on surrogate respondents for approximately half of the cases. Less occupational information was obtained from the surrogates than from the cases directly interviewed (table 2). Using cases in this study, we have previously evaluated the validity of wives’ reports on their husbands’ occupational and smoking histories (26). Wives correctly reported the cigarette smoking habits of their husbands, but they tended to give incomplete employment histories. Reporting was somewhat better for the last job held and for jobs associated with increased lung cancer risk. The necessity of surrogate interviews for some cases may have introduced misclassification, however.

The sample size for this study was determined largely by considerations related to risk factors other than occupation (8, 26). Both the prevalence of exposure and the associated risk influence statistical power for an investigation of any particular size. In the context of a population-based study, statistical power may be limited by the low prevalence of exposure in many occupations and the high likelihood that most associated risks are small. For example, this investigation’s power is 1.0 for an exposure reported by 5% of male controls with an associated OR of 4.0, but it is only 0.69 if the prevalence is 2.5% and the OR is 2.0. Because of the limited power of small studies, Doll and Peto (2) have recommended a study of 10,000 lung cancer cases and an equal number of controls to evaluate fully occupation and other risk factors for lung cancer.

Other recent case-control studies have also addressed occupational risk factors for lung cancer in the general population of the United States. Comparisons among these studies and the present study are limited by differing methodologies, differing prevalences of exposure, and potential differences in exposures sustained by workers in the various regions. For example, in areas with a high prevalence of shipyard employment, exposure in that industry has been associated with increased lung cancer risk (5). In New Mexico we found no excess risk for shipyard employment (table 3), but the CI was wide. The construction industry has also been associated with lung cancer (smoking-adjusted OR= 1.4; 90% CI= 1.0-1.8) in a case-control study in Florida (27), and numerous construction trades have also been implicated. In our study the construction industry itself and most construction-related occupations did not increase lung cancer risk. We did not find increased risk for jobs involving asbestos exposure (table 3), in contrast to the findings of others (28, 29).

Significantly increased risks were found for welders and for underground miners (table 3). Welding involves exposure to metals and to toxic gases that may affect the lungs (30). Additionally, welders may work in environments contaminated by agents associated with lung cancer, e.g., shipyard welders may be exposed to asbestos from the activities of other workers. We found increased risks for welders in all industries; the excess persisted when those with shipyard experience were excluded. The smoking-adjusted ORs in this study were higher than those found in most previous studies of welders (table 4) (31). The welders in our study had worked in diverse industries that may have involved exposures other than welding that also increased lung cancer risk.

Underground workers may be exposed to radon daughters, diesel exhaust, and silica (32). Radon daughters contaminate the air in uranium and other underground mines and are an established cause of lung cancer (33). Diesel exhaust and silica are both suspect human carcinogens (34, 35). Thus our finding of increased risk for lung cancer in underground miners is biologically plausible. We found increased risk not only for uranium miners but also for miners who had never worked in uranium. With the exception of coal mining, the lung cancer problem in mining other than uranium has not been extensively studied in the United States, and further investigations are needed to determine the types of mining that increase risk and the associated exposures.

Estimates of the proportion of lung cancer attributable to occupation have been controversial (2–4, 36). They have been made with a variety of approaches, generally descriptive rather than based on analytical investigation (4). The estimates are wide ranging (4). Of the recent estimates, those proposed by Doll and Peto (2) are in the middle of the range: 15% of incidence in U.S. males and 5% in U.S. females. We found that 14% of lung cancer in the males in our study population was attributable to employment in any high-risk industry or occupation. This figure closely agrees with that proposed by Doll and Peto (2) and demonstrates that occupational exposures have had an important and measurable effect on lung cancer occurrence in the United States.

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