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The Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer by Usual Occupation and Industry in the Detroit Metropolitan Area

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This case-referent study assesses occupational risk factors associated with lung cancer, utilizing colon and rectum cancer referents. Complete occupational and tobacco use histories were obtained by telephone interview for 5,935 incident lung cancer cases and 3,956 incident colon and rectum cancer referents. The analysis included 43 usual occupational groups and 48 usual industry groups comprised of at least 10 cases. Among all cases, there were significant elevated risks for excavating and mining workers (OR = 4.01), furnace workers (OR = 3.11), armed services personnel (OR = 3.10), agricultural workers (OR = 2.05), driver sales (OR = 2.21), mechanics (OR = 1.72), painters (OR = 1.96), and drivers (OR = 1.88). Industries with significant elevated lung cancer risk included farming (OR = 2.21), mining (OR = 2.98), and primary ferrous metals manufacturing (OR = 2.43). Analyses of white and black men separately revealed that the excess of lung cancer among mechanics is restricted to black males (OR = 4.16). The risk of lung cancer among armed services personnel is higher among black men (OR = 10.54) than among white men (OR = 3.06). Five of the occupations observed more often among lung cancer cases have probable exposure to diesel exhaust.

Key words: occupational cancer etiology, epidemiology, farming, military service, diesel exhaust, asbestos, blacks

INTRODUCTION

An increasingly important area of research into the etiology of cancer is the investigation of workplace exposures to putative carcinogens [Cullen et al., 1990]. Although the proportion of cancers attributable to occupational exposures is not well-defined, the identification and prevention of occupationally induced cancers is an important national health concern [Spiritas et al., 1978; Baker et al., 1989]. Occupational cancer surveillance is one approach that has been utilized to develop and refine specific hypotheses regarding occupational cancer etiology. This approach also can lead to prevention by supplementing and confirming studies that have identified or suggested cancer risks in the workplace.

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Many surveillance studies have been based upon the occupation and industry information reported on death certificates [Milham, 1983; Guralnick, 1962; Dubrow and Wegman, 1982; Young and Russel, 1926; Reidmiller et al., 1987; Singleton and Beaumont, 1989; MacCubbin et al., 1986]. Death certificate studies are popular because they are inexpensive and the data are readily available. However, the shortcomings of death certificate data for occupational cancer research have been well-documented [Schade and Swanson, 1988; Olsen et al., 1990; Dubrow et al., 1987; Balarajan, 1985; Schumacher MC, 1986; Steenland and Beaumont, 1984]. Other studies have utilized cancer registry data [Williams et al., 1977; Davis and Martin, 1990], institutional data [Decouflé et al., 1977], record linkage data [Petersen and Milham, 1980; Whorton et al., 1983], company records [Barrett and Belk, 1977; Kerr, 1978], and more recently, job-exposure matrices [Siemiatycki et al., 1982]. Many of the surveillance studies are restricted to white males [Guralnick, 1962; Dubrow and Wegman, 1982; Young and Russel, 1926; Siemiatycki et al., 1982; Petersen and Milham, 1980]. Only a few studies obtained complete occupational and cigarette smoking histories [Williams et al., 1977; Decouflé et al., 1977; Siemiatycki et al., 1982].

The National Institute for Occupational Safety and Health has designated lung cancer as one of its top seven priorities among occupational illnesses [Millar, 1988]. Some occupational lung carcinogens have been identified [Swanson, 1988], but more accurate information is required to refine hypotheses and inform prevention programs. This study presents results of a case-referent analysis of usual occupation and industry among 5,935 lung cancer cases and their comparison group from the Detroit metropolitan area. It provides more accurate assessment of occupational lung cancer risks than many earlier studies by utilizing complete lifetime employment histories and cigarette smoking habits to investigate the association between lung cancer and work.

This report identifies new occupations and industries in which lung cancer risk is elevated, provides supporting evidence for previous studies that have suggested certain workplace risks for lung cancer, and elucidates differences in occupational lung cancer risks between black and white males.

Extensive reviews of the occupational health and safety literature describe the paucity of data regarding work-related hazards among blacks in general [Robinson, 1984 and 1987], with specific reference to the exclusion of blacks in studies of occupational cancer risks [Robinson, 1984; Kipen et al., 1991]. In our review of case-referent or cohort studies, we observed that few studies included blacks. When blacks are included in these studies, results are often grouped with whites because there are very few blacks in the study. A recent review of the occupational cancer epidemiology literature revealed that only 14 of 116 articles published in four journals between 1984 and 1987 provided information on non-whites and none of these studies evaluated potential cofounders, such as cigarette smoking [Kipen et al., 1991].

MATERIALS AND METHODS

The Occupational Cancer Incidence Surveillance System (OCISS) is a population-based study of occupational risk factors for selected cancers occurring among residents of the Detroit metropolitan area. OCISS was developed as a complement to the Metropolitan Detroit Cancer Surveillance System (MDCSS), which is a population-based cancer reporting system for the same three-county area. MDCSS is a founding participant in the National Cancer Institute's SEER (Surveillance, Epidemiology, and End Results) program [Swanson and Brennan, 1981]. Cases are selected through the MDCSS rapid reporting system, which enables investigators to enroll patients into studies within 2 to 6 weeks after diagnosis. Incident cancers occurring among white and black females and males between the ages of 40 and 84 are enrolled into the study. Cancers selected for OCISS include: lung and bronchus, colon, esophagus, urinary bladder, rectum, liver, salivary glands, stomach, eye, melanoma of the skin, and mesothelioma.

This first analysis of occupational cancer risks from OCISS data is restricted to cancers of the lung and bronchus, since data collection is complete for this site. Data collection also has been completed for the referent group; patients diagnosed with cancer of the colon or rectum. Persons diagnosed with cancers of the colon or rectum constitute the most appropriate referent group within OCISS because their cigarette smoking patterns are similar to those of the general population. Furthermore, a comparison of the occupational distribution of the referent group with that of the Detroit area general population for the 1980 census also revealed patterns similar to the general population. There are 5,935 lung and bronchus cancer patients in the case group and 3,956 colon and rectum cancer patients in the referent group.

Subjects or their surrogates (spouse or other first degree relative of the subject) were interviewed by telephone. Telephone interviews were utilized rather than personal interviews to reduce study costs. With more than 20,000 interviews conducted to date, telephone interviews were the most practical method of data collection [Swanson et al., 1985]. The interview obtained a complete lifetime occupational history, a lifetime smoking history, an adult medical history, demographics, and a residential history. The overall response rate for the OCISS to date is 93.4%.

The lifetime work history obtained includes the occupation and industry titles of all jobs ever held, a complete description of the duties performed, the dates each job began and ended, and whether the job was full- or part-time. Coding of occupations is based primarily upon information provided in the description of the duties performed, rather than on the job title. This enables the coder to utilize specific codes that are more likely to provide leads for exposures that should be investigated in future studies. Occupation and industry data obtained by the telephone interview are coded according to the 3-digit codes of the 1980 U.S. Census Bureau classification [U.S. Department of Commerce, 1982]. Grouped codes were created by combining appropriate 3-digit codes for occupations or industries with probable similarities in work exposures. The grouped codes were created to combine jobs with similarities in exposures, decrease the number of comparisons made in the analysis, and ensure that there are adequate numbers of subjects in most groups for analysis. The grouped codes for occupations and industries are based on reviews of the literature and consultations with an industrial hygienist and an occupational physician. Usual occupation and industry are defined by summing the total number of months a person was employed in a specific industry or occupation over the entire work history and then selecting the occupation and industry for which the person had accumulated the largest number of months of exposure. The groups of occupations and industries categorized as unexposed are those with the least potential for exposure to carcinogenic agents. A list of the occupations and industries defined as unexposed is shown in the Appendix. Selection of unexposed occupations and industries was made in the same manner that exposed occupations and industries were grouped; by utilizing published information and through consultation with an industrial hygienist and an occupational physician. This analysis is concerned with usual occupation and industry, utilizing both grouped codes and individual 1980 Census Bureau codes. Usual occupational or industry group (used in Tables II–VI) refers to codes combined on the basis of similarities in exposure, while specific occupation or industry (used in Tables VII and VIII) refers to one defined by a single code.

A case-referent analysis was performed to identify industries and occupations with high risk for lung cancer. Maximum likelihood estimates of the odds ratio for usual occupations and industries were obtained using unconditional logistic regression [Breslow and Day, 1980; Breslow, 1976]. Odds ratios and their respective confidence intervals were calculated for usual occupation and industry categories that included at least 10 cases.

RESULTS

Table I compares the distribution of cases (lung and bronchus cancers) and referents (colon and rectum cancers) in terms of race, gender, age at diagnosis, cigarette smoking status, pack years of cigarette smoking, and interview outcome. These data indicate that there is a larger proportion of white females in the colon and rectum cancer referent group than in the lung cancer case group and a larger proportion of black males in the lung cancer case group than in the referent group. The age distribution of the study subjects also differs by cancer site, since colon and rectum cancers occur at older ages than lung and bronchus cancers. The cigarette smoking patterns indicate substantially higher levels of smoking among lung cancer cases than among colon and rectum cancer referents. The analysis takes these differences into account by adjusting the odds ratio estimates for age at diagnosis, cigarette smoking history, and, where appropriate, race and gender.

The interview was conducted with the subject for 46.3% of the lung cancer cases, compared to 72.5% of the colon and rectum cancer referents. Due to the higher mortality rate among the lung cancer cases, interviews with surrogates for deceased subjects were conducted with 39.2% of the lung cancers, compared to 13.2% of the colon and rectum cancer referents. The proportion of interviews conducted with surrogates for persons too ill to be interviewed was about the same for both study groups (Table I).

Comparisons between white and black males were made for four broad occupational groups that had potential for exposure to carcinogens in the workplace. In these comparisons, the odds ratios for black males were higher than those for white males for all four occupational groups (Table II). A similar comparison for industry groups found significantly elevated odds ratios for mining for white males only (OR = 3.21, CI = 1.02–10.05) and for business and repair for black males (OR = 3.17, CI = 1.14–8.86).

The remaining tables present data for analysis of usual occupation for 43 occupational groups and 48 industry groups, each of which included at least 10 cases and had some potential for exposure to carcinogens. In Tables III and IV, results are presented for all cases and referents in the study combined. For usual occupation (Table III), the largest significant elevated risk is observed for excavating and mining workers (OR = 4.01), furnace workers (OR = 3.11), and armed services personnel

TABLE I. Occupational Cancer Incidence Surveillance Study (OCISS): Characteristics of Lung Cancer Cases and Colon and Rectum Cancer Referents

	Cancer site			
	Lung and bronchus		Colon and rectum	
	No.	(%)	No.	(%)
Race and gender				
White males	2,961	(49.9)	1,600	(40.4)
Black males	957	(16.1)	381	(9.6)
White females	1,622	(27.3)	1,593	(40.3)
Black females	395	(6.7)	382	(9.7)
Total	5,935	(100.0)	3,956	(100.0)
Age at diagnosis				
40–44	114	(1.9)	54	(1.3)
45–49	232	(3.9)	107	(2.7)
50–54	448	(7.5)	226	(5.7)
55–59	888	(15.0)	386	(9.8)
60–64	1,121	(18.9)	616	(15.6)
65–69	1,165	(19.6)	736	(18.6)
70–74	995	(16.8)	664	(16.8)
75–79	636	(10.7)	663	(16.8)
80–84	336	(5.7)	504	(12.7)
Total	5,935	(100.0)	3,956	(100.0)
Cigarette smoking status				
Ever	5,511	(92.9)	2,137	(54.1)
Never	424	(7.1)	1,813	(45.9)
Total	5,935	(100.0)	3,950	(100.0)
Pack years of cigarette smoking				
Nonsmoker	425	(7.6)	1,814	(47.5)
<30	811	(14.6)	824	(21.6)
30–59	2,084	(37.6)	720	(18.8)
60–89	1,152	(20.8)	272	(7.1)
>90	1,075	(19.4)	193	(5.0)
Unknown	388		133	
Total	5,935	(100.0)	3,956	(100.0)
Interview outcome				
Subject interview	2,750	(46.3)	2,867	(72.5)
Surrogate interview for subject too ill to be interviewed	857	(14.5)	567	(14.3)
Surrogate interview for deceased subject	2,327	(39.2)	521	(13.2)
Total	5,934	(100.0)	3,955	(100.0)

(OR = 3.10). Next, there are groups of occupations with risk levels approximately twice as high as the comparison group: agricultural workers, driver sales, painters, and drivers. Other occupations with odds ratios significantly greater than 1.0 were motor vehicle mechanics, metal finishers, machine operators, machine repairers, production inspectors, and assemblers.

Analysis of usual industry showed significantly elevated risk only for farming,

TABLE II. Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer by Occupational Groups for White Males and Black Males

Occupation groups[a]	Cases no.	Controls no.	Adjusted odds ratio[b]	95% confidence interval
White males				
Service occupations	133	79	1.21	(.86, 1.70)
Farming, forestry, and fishing	37	23	1.92	(1.02, 3.61)
Precision production, craft, and repair	779	402	1.38	(1.15, 1.65)
Operators, fabricators, and laborers	954	384	1.73	(1.44, 2.05)
Black males				
Service occupations	73	29	2.75	(1.36, 5.54)
Farming, forestry, and fishing	26	9	2.35	(.74, 7.47)
Precision production, craft, and repair	156	49	2.68	(1.48, 4.85)
Operators, fabricators, and laborers	459	199	1.90	(1.20, 3.00)

[a]Unexposed groups are Managerial and professional specialities and Technical sales and administrative support occupations.
[b]Adjusted for age at diagnosis and smoking.

mining, and ferrous primary metal manufacturing (Table IV). Several other categories had odds ratios of 2.0 or greater, but the confidence intervals were not significant at the 95% level: wood manufacturing (OR = 2.28), farm sales (OR = 4.19), oil and gasoline sales (OR = 2.24), miscellaneous repair (OR = 2.55), and other transportation manufacturing (OR = 2.88).

Analyses of usual occupation and industry also were conducted for white and black males (Tables V and VI). Many of the occupations showing a significantly elevated risk for the total population of cases also are increased among white males (Table V). Drivers and driver sales occupations show a greater than twofold elevated risk among white males, while the excess among mechanics is restricted to black males, who have an elevated risk of 4.16. The odds ratio for armed services personnel is substantially higher among black males (OR = 10.54) than among white males (OR = 3.06).

Assessing risk by industry among white and black males separately (Table VI), there is an elevated risk for white males in mining and in ferrous primary metal manufacturing industries. No industries showed elevated risks among black males, but there was a significantly reduced risk among black males employed by the post office.

In Tables VII and VIII, results of an analysis, for males of usual occupation and industry by individual 3-digit 1980 Census Bureau codes are presented to determine whether risks observed in grouped occupations or industries are associated with specific jobs. This analysis reveals that, within the group of food preparation workers, risk is concentrated among butchers and meat cutters (OR = 3.24). The highest odd ratios for usual occupation are observed for structural metal workers (OR = 9.00), mining machine operators (5.03), concrete and terrazzo finishers (OR = 7.57), painting and spray painting machine operators (OR = 4.50), and slicing and cutting machine operators (other than food) (OR = 4.59). Two specific usual industries are significantly elevated: blast furnaces, steelworks, rolling and finishing mills (OR = 2.14) and armed services (OR = 2.31).

TABLE III. Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer by Usual Occupational Groups, All Cases Combined*

Occupation groups[a]	Cases no.	Controls no.	Odds ratio[b]	95% confidence interval
Police officers	48	26	1.06	(.66, 2.02)
Inspectors	9	11	.55	(.21, 1.45)
Chemical workers	47	42	.98	(.59, 1.62)
Engineers, NEC*	17	10	1.20	(.50, 2.89)
Electrical workers	70	48	.98	(.63, 1.51)
Engineers, industrial	52	51	.77	(.48, 1.23)
Agricultural workers	70	35	2.05[c]	(1.24, 3.40)
Health care professionals	37	45	.67	(.41, 1.11)
Driver sales	45	16	2.21[c]	(1.13, 4.33)
Sales workers with misc. exposures	76	58	.84	(.56, 1.27)
Laborers	149	69	1.39	(.97, 1.99)
Postal workers	26	17	1.15	(.57, 2.33)
Stock clerk	67	30	1.32	(.81, 2.17)
Assemblers	316	146	1.49[c]	(1.15, 1.92)
Production inspectors	138	55	1.73[c]	(1.19, 2.50)
Private household workers	34	51	.62	(.36, 1.05)
Firemen	17	10	1.33	(.53, 3.35)
Janitors	102	60	1.25	(.84, 1.85)
Hairdressers/barbers	20	21	.76	(.37, 1.55)
Personal service workers	10	6	2.20	(.65, 7.43)
Wood workers	69	34	1.12	(.70, 1.81)
Mechanics, motor vehicles	118	48	1.72[c]	(1.15, 2.59)
Machine repairers	90	43	1.61[c]	(1.04, 2.48)
Molders	24	13	1.78	(.79, 3.98)
Pickling process workers	10	2	2.09	(.44, 9.87)
Tool die makers	192	114	1.08	(.80, 1.44)
Masons	37	16	1.79	(.91, 3.51)
Painters	97	35	1.96[c]	(1.23, 3.13)
Plumbers	42	18	1.29	(.69, 2.39)
Other craftsmen	106	47	1.50	(.98, 2.28)
Metal finishers	212	89	1.69[c]	(1.24, 2.30)
Excavating and mining workers	19	6	4.01[c]	(1.33, 12.14)
Furnace workers	62	17	3.11[c]	(1.65, 5.83)
Printers	18	19	.80	(.38, 1.71)
Power plant operators	13	8	1.31	(.47, 3.67)
Machine operators	147	66	1.54[c]	(1.09, 2.18)
Textile workers	12	15	1.08	(.42, 2.78)
Dry cleaning and laundry workers	21	14	1.24	(.56, 2.75)
Welders	95	47	1.43	(.94, 2.17)
Drivers	238	86	1.88[c]	(1.37, 2.58)
Railroad workers	14	8	1.27	(.45, 3.53)
Material moving workers	105	60	1.07	(.73, 1.58)
Armed services personnel	37	9	3.10[c]	(1.36, 7.09)
Computer technicians	20	21	.65	(.33, 1.28)
Health care technicians	49	35	1.22	(.73, 2.05)
Food preparation workers	82	44	1.55	(.99, 2.43)
Unexposed	2,165	2,040		

*NEC, not elsewhere classified.
[a]Includes occupation groups with 10 or more cases.
[b]Adjusted for age at diagnosis, race, smoking and gender.
[c]Odds ratios with significant 95% CI.

TABLE IV. Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer by Usual Industry Groups, All Cases Combined

Exposed industry groups[a]	Cases no.	Controls no.	Odds ratio[b]	95% confidence interval
Farming	54	24	2.21[c]	(1.20, 4.06)
Mining	23	7	2.98[c]	(1.06, 8.39)
Construction	383	162	1.23	(.94, 1.61)
Non-ferrous primary metal manufacturing	33	13	1.65	(.78, 3.52)
Ferrous primary metal manufacturing	152	41	2.43[c]	(1.56, 3.79)
Clay manufacturing	21	13	.99	(.45, 2.21)
Food manufacturing	82	37	1.27	(.79, 2.06)
Beverage manufacturing	18	14	.69	(.30, 1.58)
Textile manufacturing	11	12	.91	(.33, 2.53)
Printing	54	41	.67	(.40, 1.11)
Drug manufacturing	17	8	.94	(.35, 2.52)
Chemical manufacturing	29	20	.73	(.37, 1.47)
Rubber and plastic manufacturing	44	22	1.22	(.66, 2.25)
Wood manufacturing	21	6	2.28	(.81, 6.43)
Fabricated metal manufacturing	92	56	.96	(.64, 1.46)
Machinery manufacturing	201	114	.92	(.68, 1.25)
Computer manufacturing	25	22	.97	(.47, 1.99)
Appliance manufacturing	30	18	.75	(.38, 1.47)
Automobile manufacturing	1364	701	1.03	(.86, 1.23)
Air and space manufacturing	15	10	.73	(.29, 1.81)
Gas and electric utilities	39	41	.53[c]	(.31, .90)
Automobile sales	63	29	1.15	(.68, 1.95)
Lumber sales	18	7	1.84	(.66, 5.14)
Hardware sales	21	16	.63	(.30, 1.36)
Drug sales	7	15	.33[c]	(.11, .98)
Apparel sales	18	19	.85	(.40, 1.81)
Farm sales	8	2	4.19	(.64, 27.21)
Oil and gasoline sales	38	11	2.24	(.99, 5.04)
Liquor sales	7	6	.69	(.18, 2.65)
Miscellaneous sales	35	27	.75	(.41, 1.36)
Department stores	53	58	.64	(.41, 1.01)
Building services	19	13	.70	(.30, 1.62)
Automobile repair	57	19	1.56	(.85, 2.87)
Miscellaneous repair	13	5	2.55	(.69, 9.48)
Private households	46	63	.60[c]	(.37, .97)
Hotels and motels	15	12	1.01	(.39, 2.56)
Dry cleaners and laundries	38	27	1.08	(.58, 2.02)
Beauty salons	26	24	.68	(.34, 1.35)
Hospitals	30	27	.80	(.55, 1.16)
Medical offices	91	78	.79	(.43, 1.47)
Membership organization	6	6	.57	(.16, 2.03)
Engineering services	12	11	.76	(.29, 2.00)
Armed services	53	27	.93	(.52, 1.65)
Water utilities	38	21	.83	(.44, 1.55)
Miscellaneous unskilled labor services	12	5	1.67	(.44, 6.36)
Other transportation manufacturing	24	7	2.88	(.89, 9.36)
Miscellaneous manufacturing	31	17	1.16	(.55, 2.45)
Waste materials sales	11	6	.79	(.24, 2.58)
Railroads	35	21	1.37	(.70, 2.66)
Bus and truck transport	166	61	1.20	(.82, 1.75)
Post office	43	29	.78	(.44, 1.39)
Water transport	9	5	.64	(.19, 2.15)
Air transportation	6	4	.97	(.23, 4.20)
Unexposed	2,140	1,908		

[a]Includes industry groups with 10 or more cases.
[b]Adjusted for age at diagnosis, race, gender and smoking.
[c]Odds ratios with significant 95% CI.

TABLE V. Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer Among Males by Usual Occupational Groups and Race (Occupations With Significantly Elevated Risk)

Occupation	Cases	Controls	Odds ratio[a]	Confidence interval[b]
White males				
Driver sales	42	14	2.17	1.07–4.39
Assemblers	192	91	1.57	1.13–2.17
Production inspectors	93	33	1.89	1.19–3.02
Machine repairers	75	34	1.80	1.11–2.92
Metal finishers	160	55	2.23	1.51–3.28
Furnace workers	31	7	2.96	1.18–7.42
Machine operators	97	41	1.62	1.05–2.50
Drivers	187	54	2.40	1.65–3.48
Armed services personnel	25	7	3.06	1.13–8.25
Food preparation workers	40	14	2.46	1.17–5.16
Black males				
Mechanics, motor vehicles	31	6	4.16	1.27–13.64
Armed services personnel	12	1	10.54	1.07–104.02

[a]Adjusted for age at diagnosis and smoking; includes 41 occupations with 10 or more cases for white males and 25 for black males; only those with significantly elevated odds ratios are shown.
[b]$p < .05$.

TABLE VI. Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer Among Males by Usual Industry Groups and Race (Industries With Significantly Elevated or Reduced Risk)

Industry	Cases	Controls	Odds ratio[a]	Confidence interval[b]
White males				
Mining	20	5	3.57	1.13–11.24
Ferrous primary metal manufacturing	105	31	2.07	1.26–3.40
Black males				
Post office	16	13	.24	.08–.73

[a]Includes 45 industry groups for white males and 17 industry groups for black males (those with 10 or more cases); adjusted for age at diagnosis and smoking.
[b]$p < .05$.

DISCUSSION

As with any study, the results must be interpreted within the context of the study's strengths and limitations. The strengths of this study exceed its limitations. First, the outcome data are obtained from hospital abstracts of incident cancer cases. Thus, the accuracy and specificity of the diagnosis is greater than one can obtain from death certificates [Percy et al., 1981]. Second, the information about occupation and industry includes a lifetime history obtained by interview, rather than a single entry from death certificates. Analyses performed utilizing the OCISS data show a 30–50% error rate for death certificate employment data compared to interview data [Schade and Swanson, 1988]. A recent study also observed inaccuracies in death certificate employment information [Olsen et al., 1990]. Third, there has been a need for some time for a study that encompasses a large number of lung cancer cases [Peto, 1981].

TABLE VII. Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer Among Males by Specific Occupation*

Occupational group	Cases	Controls	Odds ratio[a]	Confidence interval
Farmers	32	13	2.36	1.07– 5.22
Concrete and terrazzo finishers	9	1	7.57	.85–67.63
Structural metal workers	12	1	9.00	1.01–80.38
Mining machine operators	16	5	5.03	1.50–16.86
Butchers and meat cutters	29	6	3.24	1.20– 8.76
Inspectors, testers, and graders	75	21	2.15	1.24– 3.74
Grinding, abrading, buffing, and polishing machine operators	85	36	1.74	1.09– 2.79
Painting and spray painting machine operators	37	6	4.50	1.71–11.82
Furnace, kiln, and oven operators	39	12	2.45	1.13– 5.35
Slicing and cutting machine operators	23	4	4.59	1.45–14.54
Assemblers	179	59	1.94	1.32– 2.83
Drivers of heavy trucks	166	48	2.31	1.56– 3.42
Driver sales workers	42	14	2.39	1.18– 4.82
Armed services personnel	37	9	3.21	1.39– 7.41

*Analysis includes occupations with 10 or more cases; only those with a significant CI or an OR of 2.0 or greater are shown.
[a]Adjusted for age at diagnosis, race, and smoking.

TABLE VIII. Occupational Cancer Incidence Surveillance Study (OCISS): Risk of Lung Cancer by Specific Industry for Males*

Industry group	Cases	Controls	Odds ratio[a]	Confidence interval
Agricultural production, crops	36	13	1.99	.92– 4.30
Blast furnaces, steelworks, rolling and finishing mills	115	30	2.14	1.34– 3.43
Lumber and construction materials sales	9	2	4.98	.94–26.54
Armed services	35	9	2.31	1.01– 5.28

*Analysis includes industries with 10 or more cases; only those with a significant CI or an OR or 2.0 or greater are shown.
[a]Adjusted for age at diagnosis, race, and smoking.

This study includes nearly 6,000 cases, enabling the investigators to study occupational risk for many occupations. Fourth, complete lifetime tobacco use histories are obtained for all OCISS subjects. As a result, the occupation risks all take into account the cigarette smoking history of the subjects. For a study of lung cancer, such data are essential to the accurate assessment of risk associated with the workplace [Blair et al., 1988]. Fifth, by including both black and white subjects, this study will begin to elucidate occupational lung cancer risk differences between these two racial groups. Finally, this study has an exceptionally high response rate: 94.3% for lung cancer cases and 95.4% for colon and rectum cancer referents.

This study has some limitations. The large number of comparisons that have been made in this analysis may have produced some results that are due to chance alone (5% at the alpha level selected). The potential for this problem was reduced by grouping occupations and industries with similar exposures to limit the number of comparisons. In addition, the analysis was restricted to occupation and industry groups including at least 10 cases.

As in any case-referent study, the choice of a referent group is important to the outcome of the study. Colon and rectum cancer cases were selected as referents because they have not been shown to be associated with cigarette smoking. Similarly, they have been linked with few occupations or exposures to chemical carcinogens [Swanson, 1988]. Although there is some suggestion of an association between asbestos exposure and a modest increase in colorectal cancers, the risk is substantially lower than that observed across many studies for respiratory cancers [Frumkin and Berlin, 1988]. Furthermore, our comparison of the cigarette smoking habits of colon and rectum cancer cases with the general population produced similar patterns, as did our comparison of the occupational distribution of these cancer cases with the Detroit area general population. An association was observed between several asbestos-related occupations and lung cancer. Thus, utilization of this series of referents allowed us to detect this relationship. At most, the level of risk observed in this study may be somewhat lower than the actual risk. The use of cancer cases as referents has advantages in terms of study efficiency and costs. Additionally, utilization of cancer cases as referents should reduce interview or recall bias, since both the case group and the comparison group should be equally motivated to recall past lifestyle habits and potential work exposures [Linet and Brookmeyer, 1987]. In this study, the colon and rectum cancer cases were the most appropriate referent group, since all other cancer sites included in the study have been associated with cigarette use *and* with occupational carcinogens. There also are some limitations to having a referent group constituted by cancer cases [Linet and Brookmeyer, 1987]. The interpretation of the odds ratio estimate is dependent on the exposures of the cancer controls. As described above, our analyses indicate that the colon and rectum cancer referent group is not characterized by the same risk factors as the lung cancer case group.

Another limitation pertains to any study that relies exclusively on interview information: specific exposure data are not available from which one can determine the agent or agents responsible for the observed elevations in risk seen for specific occupation groups. While this study did not obtain exposure data, it does provide more accurate and detailed information than has been included in many previous studies by utilizing complete lifetime work histories and tobacco use histories.

This study presents some interesting leads for further investigation. First, evidence for an association between lung cancer and occupations with possible diesel exhaust exposure is provided. There are five occupations with such exposure potential: drivers of heavy trucks, driver sales, farmers, mechanics, and mining machine operators. The occupation most likely to have high levels of continuous exposure to diesel exhaust and to experience that exposure in a confined area has the highest elevated risks: mining machine operators (OR = 5.03). Drivers of heavy trucks, drivers involved in sales, and farmers have elevated odds ratios of about 2.3, while motor vehicle mechanics have elevated odds ratios of 1.7. This pattern suggests that persons likely to have the greatest exposure to diesel exhaust exhibit higher risk of lung cancer than those likely to have lower levels of diesel exhaust exposure. Experimental studies have shown an association between exposure to diesel exhaust and the development of lung cancer [NIOSH, 1988]. Epidemiologic studies suggest that diesel exhaust may act as a human lung carcinogen [NIOSH, 1988; Schenker, 1980; Steenland, 1986; Fraser, 1986; Steenland et al., 1990; Boffetta et al., 1988]. Many of the epidemiologic studies suffer from lack of exposure data, as does this study [Steenland et al., 1990; Boffetta et al., 1988; Boffetta et al., 1990]. However, the consistency observed in the association between occupations with likely diesel exhaust exposure and lung cancer in this study and in others lends some credibility to this association. In this study, we also observe increasing risk of lung cancer across occupations that would have increasing levels of exposure to diesel exhaust.

A new lead provided by this study is the observation of an association between farming and lung cancer. After adjusting for cigarette smoking, we see an elevated risk of 2.3 among males whose usual occupation is farmer. Previous studies have noted a deficit of lung cancer among farmers [Milham, 1983; Williams et al., 1977; Zahm et al., 1989; Blair et al., 1985]. In one study, occupational information was obtained from the medical record with information found for less than half of the study subjects [Zahm et al., 1989]. Certainly, one category of exposures that one would postulate from this association would be pesticides and other chemicals utilized on farms. Another possibility is diesel exhaust, since tractors utilized in the time period when initiation and promotion would have occurred produced high levels of exhaust directly onto the tractor driver. A review of the interview information indicated that many of these men farmed in southern states, such as Mississippi, Alabama, or Arkansas. Perhaps some regional variation in exposure partially explains this observation. The OCISS study provides a very strong indication that farmers are at elevated risk of lung cancer, particularly when one takes cigarette smoking habits into account. Based on these data, it is not good public health practice to continue to view the occupation of farmer as "protective" for lung cancer.

Asbestos is another specific agent that is implicated by this study's observations. Some of the risk among mechanics (OR = 1.72; for black males, OR = 4.16) may be due to exposure to asbestos from brake linings [NIOSH, 1975a; Rohl et al., 1976; Nicholson et al., 1981]. Motor vehicle mechanics also are exposed to lead [Bridboard, 1977] and, as noted above, diesel exhaust. Structural metal workers (OR = 9.00) also may be exposed to asbestos, as may furnace, kiln, and oven operators (OR = 2.45) [NIOSH, 1976a; NIOSH, 1976b]. An association between working as concrete and terrazzo finishers and lung cancer (OR = 7.57) further implicates asbestos, as well as silica, dusts, and amines that are contained in the adhesives utilized [Karches, 1978].

Other excesses of lung cancer cases among certain occupations presented here have been observed in previous studies. The elevated risk among painters, when the detailed occupation codes were analyzed, is concentrated among painting machine operators working in an industrial setting, rather than among house painters. This specific detail has not been previously observed. One would expect that spray painting machine operators have greater potential for exposure to paint particulates than painters using brushes by hand. Some agents found in paints have been shown to be human lung carcinogens, including lead and cadmium [NIOSH, 1975b; Swanson, 1988]. Slicing and cutting machine operators accounted for the excess risk observed in the general category of machine operators. Exposure to cutting oils may be responsible for some of the excess risk observed. Previous studies have suggested an association between cutting oils and lung cancer [Swanson, 1988]. There also is evidence that these fluids contain some known human carcinogens, such as nitrosamines [NIOSH, 1976c]. The elevated risk observed among metal finishers may be due to exposures to metal dusts and particulates. Previous studies have observed elevated lung cancer risk among various groups of steelworkers [Redmond et al., 1981; Steenland and Beaumont, 1989; Finkelstein and Wilk, 1990]. An association between metal mining and lung cancer has been reported [Swanson, 1988]. This study observed an association between working as butchers and meat cutters and lung cancer. This relationship has been shown in previous studies [Fox et al., 1982; Doerken and Rehpenning, 1982; Johnson and Fischman, 1982], although no plausible explanation has been suggested.

An unexpected finding is the lung cancer excess among armed services personnel. The military occupational code is assigned regardless of the actual duties performed. Thus, one would expect that military personnel would have had a variety of jobs. A review of the descriptions of duties performed as described on the questionnaires did not reveal any consistency in military occupations. One lung cancer case in this group did report exposure to asbestos as a boiler inspector on board a Navy ship. Although no single job assignment seemed to provide clues to possible exposure among these military personnel, a group of these men had work assignments similar to non-military workers that had elevated risk of lung cancer in this study. Among the white males with usual occupation in military services, six were diesel mechanics, five had assignments on board ships, two were truck drivers, and eight were gunners or heavy artillery repairers. Among the black males with usual occupation in the military services, two worked on board ships, two were diesel mechanics, and one was a truck driver.

The analyses of usual industry provided some observations that complemented the assessment of usual occupation. The excess risk in the farming and mining industry groups is consistent with the observations of elevated lung cancers among farmers and mining machine operators. The excess of lung cancer among persons employed in the primary ferrous metal manufacturing industry may correspond to the excess observed among furnace workers, metal finishers, and machine operators. Previous studies investigating lung cancer risk by industry supported our results. A mortality study in New York State [MacCubbin et al., 1986] saw an increase in lung cancer in the blast furnace and steelwork industry. A recent study of incident lung cancer cases in Massachusetts [Davis and Martin, 1990] supported the association observed in this study between mining and lung cancer. In the OCISS population, those working in mines were all coal miners.

An important objective of this study is to determine whether occupation lung cancer risks differ between white and black males. It has recently been shown that, when non-whites were included in investigations of occupational cancer risk, they experienced higher mortality ratios than whites [Kipen et al., 1991]. Similarly, the OCISS results suggest that black males may experience greater excesses of lung cancer than white males when employed in the same occupational group. The analysis of very broad occupation groups reveals higher risks among blacks than among whites for all four categories that have some potential for exposure to carcinogens. Two specific occupations are associated with significant, high elevations of risk among black males: motor vehicle mechanics, which had an excess of lung cancers among black males but not among white males; and armed services personnel, with a significant tenfold excess risk of lung cancer among black males, compared to a threefold risk among white males. Perhaps the black males employed as mechanics have worked more often than white males in this occupation in settings less likely to be regulated, such as small repair shops or gas stations. The usual industry analysis produced an interesting finding: black males had a significantly lowered risk of lung cancer for postal workers, with risk lowered by 75%.

This study provides useful leads for further, more detailed investigation, especially for studies that measure specific exposures. Further study of the relationship between lung cancer and farming is mandated by these data. The potential association between lung cancer and diesel exhaust observed across several occupations warrants investigations that include measurement of exposure to diesel exhaust. More detailed assessment of the lung cancer risk among military personnel also is suggested. Reasons for the excess lung cancers observed among black males, particularly among those employed as motor vehicle mechanics or armed services personnel, must be explored. The OCISS data demonstrate the strength of investigations incorporating a population-based cancer surveillance system utilizing interview data that encompasses tobacco use information. They also indicate the need for exposure information, particularly biological measures of specific agents, such as diesel exhaust or pesticides.

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APPENDIX

APPENDIX. Occupational Cancer Incidence Surveillance Study (OCISS): Occupations and Industries Categorized as Unexposed for This Study

Occupation groups	Industry groups
Administrators	Communications
Financiers	Paper sales
Buyers/advertisers	Clothing sales
Health administrators	Food stores
Real estate sales	Department stores
Statisticians	Appliance/furniture sales
Teachers	Restaurants
Social workers/clergy	Banks
Social scientists	Real estate
Bookkeepers	Advertising
Artists	Business services
Lawyers	Personal services
Library/museum workers	Entertainment services
Writers	Legal services
Radio/TV announcers	Schools
Sales workers	Child care
Clerical workers	Social services
Communication equipment operators	Art
Food workers	Religion
Housewives	Government
Students	Justice
Unemployed	Volunteer services