Lung Cancer Risk Among Construction Workers in California, 1988–2007

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Background *Although lung cancer risks can vary by race/ethnicity and by construction occupation, these risks have not been examined extensively.*
Methods *This study analyzed 110,937 lung cancer cases identified from the California Cancer Registry between 1988 and 2007. Mean age at diagnosis, proportion diagnosed at an advanced stage, and proportion with 3-year survival were calculated for lung cancer cases employed in the construction industry. Case–control methodology was also used to assess the risk of lung cancer. Morbidity odds ratios (MORs) were estimated by conditional logistic regression.*
Results *Construction workers were found to have a significantly elevated risk for all lung cancer combined (MOR = 1.57) and for each lung cancer histologic subtype examined. All construction occupations, except managers/engineers and supervisors, had a significantly elevated risk for all lung cancer combined. Roofers and welders had the highest risks for total lung cancer and for each of the histologic subtypes. Construction workers in each of the four race/ethnicity groups also had significantly increased lung cancer risks. Compared to non-construction workers, construction workers were diagnosed at an earlier age, at a more advanced stage, and had significantly lower 3-year survival, though differences were modest.*
Conclusion *These findings justify additional reductions in carcinogenic exposures in construction, and increased support for smoking cessation programs at construction sites.* Am. J. Ind. Med. *© 2012 Wiley Periodicals, Inc.*

KEY WORDS: cancer; lung; surveillance; construction; occupational; roofer; welder; laborer; race

INTRODUCTION

In the US, lung cancer is the second most common cancer diagnosed in men exceeded only by prostate cancer, and accounts for more deaths than any other cancer [American Cancer Society, 2010]. The proportion of lung cancer cases in men attributed to occupational exposures has been estimated to range from 6% to 33% [Orenstein et al., 2010]. Construction workers are exposed to many known or suspected carcinogens, including silica, asphalt

Abbreviations: BOC, US Bureau of the Census; CCR, California Cancer Registry; CI, confidence interval; IARC, International Agency for Research on Cancer; I&O, industry and occupation; MOR, morbidity odds ratio; NHIS, National Health Interview Survey; NIOSH, National Institute for Occupational Safety and Health; NSCLC, Non-small cell lung cancer; PAH, polycyclic aromatic hydrocarbons; SE, standard error; SEER, Surveillance Epidemiology and End Results; SIR, standardized incidence ratio; SMR, standardized mortality ratio; TNM, tumor, node, metastases; US, United States of America.

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fumes, polycyclic aromatic hydrocarbons (PAHs), diesel exhaust, paints, asbestos, lead, metal fumes, and solvents [Järvholm, 2006]. It has been estimated that over half of all cancer deaths attributed to occupational exposures occurred among construction workers, and among these construction workers, lung cancer accounted for the largest proportion of occupation-attributable cancer deaths (47%)[Rushton et al., 2008].

Lung cancer risks are known to vary by race/ethnicity and across construction occupations [Haiman et al., 2006; Pukkala et al., 2009]. However, to our knowledge, lung cancer risks have not been examined in workers across four broad race/ethnicity categories of workers: non-Hispanic white, non-Hispanic black, Hispanic and Asian. In addition, few studies have examined lung cancer risks across a large number of construction occupations. The purpose of this analysis was to use data from the California Cancer Registry (CCR) to describe the risk of lung cancer, combined and for individual histologic subtypes, across 13 construction occupations, and in four broad race/ethnicity categories of workers. The histologic subtypes may represent distinct etiologic diseases and their examination may help to detect occupational determinants [Vallyathan et al., 1998].

California data were selected for analysis because: California is the most populous state in the country with the highest number of cancer cases diagnosed annually; California has large numbers of Hispanics, Asians, and African Americans; and researchers at CCR have long been interested in the role of industry and occupation in cancer etiology and incidence. The National Institute for Occupational Safety and Health (NIOSH) has been collaborating with CCR since 2007 to assign industry and occupation (I&O) codes to cancer patients identified by CCR and using these data to assess cancer risks by industry and occupation. Priority was given to coding the I&O for cancer cases whose usual industry (i.e., the industry in which the individual was longest employed) was construction.

MATERIAL AND METHODS

Study Population

The CCR is a statewide population-based cancer registry. Hospitals and other cancer treatment facilities are required to report incident malignant cancer cases to the CCR (non-melanomatous skin cancers are excluded from this reporting requirement). Physicians and other health care professionals are required to report cases who are not referred to a hospital or other cancer treatment facility. Information must be electronically reported within 6 months after the patient is admitted to the facility or care commenced (California Administrative Code title 17, § 2593).

For each case of malignant cancer identified in California, the CCR collects three types of information: demographic information, information about the cancer, and treatment information. Demographic information includes name, date of birth, race, sex, and usual (i.e., longest-held) I&O. Information on lifestyle factors, such as tobacco and alcohol usage, is not captured by the CCR. Information on the cancer includes the site of the cancer, histology, date of diagnosis, and stage at diagnosis. Finally, treatment information includes survival time in months. CCR conducts vital status follow-up by contacting California hospitals and also linking with a number of administrative databases: California death certificate file; Social Security Administration Death Master File; Social Security Administration Epidemiology file; California Department of Motor Vehicle file; the National Death Index; the California voter registration file; California birth certificate file; and, the California hospital discharge file. These linkages occur throughout the year.

State law requires that "every effort be made" to capture usual I&O on every cancer case detected by CCR (California Health and Safety Code section 103875–103885). Federal law also requires cancer registries to collect I&O data (Cancer Registries Amendment Act, Public Law 102–515). These data are captured in narrative form by registrars, and standardized systems are available for coding both industry and occupation to facilitate analysis. From 1995 to 2002, CCR coded the I&O of many of their cases using US Bureau of the Census (BOC) 1990 I&O codes [U.S. Bureau of the Census, 1992]. In addition, since 1972, the Los Angeles Cancer Surveillance Program, a California regional registry, has been coding the I&O of many of their cases using 1970 and 1980 BOC I&O codes. Beginning in 2007, NIOSH began a collaboration to complete assignment of 1990 BOC I&O codes to all CCR cases that have I&O narratives. Between 1988 and 2007, a total of 2,894,256 cancer cases were identified by CCR. Of these, 1,383,468 (48%) had sufficient narrative information to code industry and/or occupation. For the remaining cancer cases, the industry and occupation fields were blank or filled with "unknown/unemployed/disabled" (26% of the total), "retired" (17%), "homemaker" (6%), "never worked" (3%), or military (0.6%). Data for most cases treated in military treatment facilities are not shared with state cancer registries. NIOSH resources were not available to assign codes to all cases with sufficient I&O narrative information. Because the priority was to assess cancer in construction workers, the I&O fields in the entire CCR database were extensively searched using 90 key words consistent with construction employment, and the identified cases were coded. Because CCR removed personal identifiers from the data prior to submission to NIOSH and because this study was considered public health surveillance, this study was exempt from consideration by the NIOSH Institutional Review Board.

Case–Control Methods

Case–control methodology was used to assess the relative risk of lung cancer across various construction occupations. Excluded from the analyses were females (of the 73,809 construction workers in the CCR database, only 3,509 [5%] were female), homemakers, those whose usual industry and occupation were unknown, those who never worked, and those in the military. Lung cancer cases were identified with the Surveillance, Epidemiology, and End Results (SEER) incidence site recode 22030 [SEER, 2003]. Lung cancer cases were included if they were between the ages of 18 years and 97 years, and were diagnosed between 1988 and 2007 (2007 was the most recent year of complete data at the time of analysis). Controls were selected from the CCR database and had one or more cancers not known to be associated with employment in the construction industry: prostate, colon, brain, kidney, testis, bone and joint, and thyroid. Up to five controls were matched to each case based on age (5-year age group), year of diagnosis group (5-year group), and race/ethnicity.

Data Analysis

SAS v. 9.2 was used for data management and analysis (SAS Institute 2008). Student's *t*-tests were used to compare age at diagnosis between construction and non-construction workers. Chi square statistics were used to compare categorical characteristics. The Cox proportional hazards regression model was performed to estimate survival time and standard error. Regression parameters (β) were derived from the equation

$$S(t, Z_i) = [S_0(t)]^{\exp(z'_i\beta)}$$

where $Z_i = 1$ for the industry/occupation of interest, otherwise $Z_i = 0$, and $t =$ survival time in months. Survival $S(t,Z_i)$ was calculated at each time level and the estimated survival proportion at 36 months was reported. Cases were followed through December 2007.

Morbidity odds ratios (MORs) were estimated by conditional logistic regression using the PROC PHREG procedure, and 95% confidence intervals were estimated using the Wald test [Rothman and Greenland, 1998]. The MORs were used to compare the proportions of construction workers among the cases and controls. MORs were also estimated for 13 construction occupations, for the four different race/ethnicity groups (i.e., non-Hispanic white, non-Hispanic black, Hispanic, and Asian), and for each 5-year time period (e.g., 1988–1992, 1993–1997, 1998–2002, 2003–2007).

RESULTS

Of the 187,862 male lung cancer cases that met the age and year of diagnosis criteria, 110,937 had information on industry and occupation and were included in the analyses (76,925 [41%] male lung cancer cases were excluded because they had insufficient narrative information to code industry or occupation, were homemakers with no other job information, or never worked). The distribution of these cases by histology and industry is provided in Table I. Adenocarcinoma accounted for the largest proportion of cases (33%). A total of 13,268 construction workers had lung cancer (Table II). Construction workers were diagnosed with lung cancer at a slightly earlier age compared to non-construction workers (construction workers = 67.1 years, non-construction workers = 67.5 years, $P < 0.01$). The mean age at diagnosis was lowest for roofers (64.7 years), and highest for plumbers (68.4 years). Construction workers were also somewhat more likely to be diagnosed at an advanced stage (corresponding to stage IIIb or IV of the TNM [tumor, node, metastases] classification [Mountain, 1997]). A total of 61.4% of construction workers were diagnosed at advanced stage versus 59.6% of non-construction workers ($P < 0.01$). The proportion diagnosed at advanced stage was highest for roofers (63.6%) and lowest for metal workers (57.6%). In addition, construction workers had a small but significantly lower 3-year survival (14.2%) compared to non-construction workers (16.2%; $P < 0.01$). The construction occupations with the lowest 3-year survival were brickmasons (12.3%), metal workers (12.6%), and roofers (12.8%) and the highest 3-year survival was among managers and engineers (17.0%).

The distribution of cancers diagnosed among the controls used in the MOR analyses is provided in Table III. Most of the controls had either prostate (63%) or colon (23%) cancer.

Construction workers were found to have a significantly elevated risk for all lung cancer combined (MOR = 1.57, 95% confidence interval [CI] = 1.54, 1.61) and for each lung cancer histologic subtype examined (Table IV). All construction occupations, except managers/engineers and supervisors, had a significantly elevated risk for all lung cancer combined and for non-small cell lung cancer (NSCLC) (Table IV). All construction occupations, except managers/engineers, supervisors, and brickmasons, also had a significantly elevated risk for small cell lung cancer and "other types" of lung cancer. The occupations with the highest risks for total lung cancer and each of the histologic subtypes were roofers and welders (Tables IV and V). Figure 1 provides evidence that the elevated risk for lung cancer among specific high risk construction occupations has changed relatively little over

TABLE I. Distribution of Lung Cancers by Histology and Industry, California, 1988–2007

Histology	ICD-O codes[a]	Construction workers (%)	Non-construction workers (%)	Total
All[b]		13,268 (100)	97,669 (100)	110,937
Adenocarcinoma	8050, 8051, 8140, 8141, 8143, 8147, 8200, 8201, 8250–8255, 8260, 8310, 8320, 8323, 8430, 8480, 8481, 8490, 8550, 8551, 8560, 8562, 8570–8576	3,880 (29)	32,498 (33)	36,378
Squamous Cell	8052, 8070–8076, 8078	3,095 (23)	21,290 (22)	24,385
Small Cell	8002, 8041–8045	1,770 (13)	11,861 (12)	13,631
Large cell	8012–8014	725 (5)	5,378 (6)	6,103
Non-Small Cell Cancer, unspecified	8046	760 (6)	5,266 (5)	6,026
Other[c]		2,235 (17)	16,275 (17)	18,510
Unknown		803 (6)	5,101 (5)	5,904

[a]International Classification of Diseases for Oncology [World Health Organization, 2000].
[b]Restricted to male cases between the ages of 18 years and 97 years, diagnosed between 1988 and 2007, and who had sufficient narrative information to code industry and/or occupation. Another 76,925 male lung cancer cases who met the age and year of diagnosis criteria were excluded because they did not have sufficient narrative information to code industry and/or occupation, were homemakers with no other job information, were military personnel, or never worked.
[c]Other includes carcinoma not otherwise specified (n = 15,097), malignant carcinoid tumor (n = 1,714), mesothelioma (N = 58), and other miscellaneous cancers (n = 1,641).

time, despite the drop in the number of lung cancer cases for most occupations.

The risk for all lung cancer combined was also significantly elevated for construction workers in each of the four race/ethnicity groups (Table VI). The risks for all lung cancer combined and NSCLC were highest in non-Hispanic blacks. The risk for small cell lung cancer was highest in non-Hispanic whites and the risk of other lung

TABLE II. Age at Diagnosis, Survival After Diagnosis and Proportion Diagnosed at Late Stage by Construction Occupation

Occupation	1990 BOC occupation codes	N	Mean age at Dx (years)	Estimated proportion surviving 3 years (SE)	Diagnosed at an advanced stage (%)[a]
All lung cancer cases		110,937	67.4	16.0 (0.001)	59.8
Construction workers[b]		13,268	67.1	14.2 (0.003)	61.4
Brickmasons	563	226	68.3	12.3 (0.02)	61.3
Carpenters	567, 569	2,169	68.1	13.5 (0.006)	62.1
Electricians	575, 576, 577	970	67.5	16.2 (0.01)	59.1
Laborers	599, 869	2,689	66.0	13.8 (0.006)	62.8
Managers and Engineers	003–199	1,029	66.7	17.0 (0.01)	60.6
Metal workers	597	219	67.6	12.6 (0.02)	57.6
Operating Engineers	844, 848, 849, 853, 855, 856	699	67.9	13.2 (0.01)	58.6
Painters	579, 583,584	1,229	66.8	13.1 (0.01)	62.8
Plumbers	585, 587	909	68.4	14.3 (0.01)	59.1
Roofers	595	312	64.7	12.8 (0.02)	63.6
Supervisors	243, 303, 307, 553–558, 843	1,130	67.3	16.6 (0.01)	60.1
Welders	783	216	67.3	13.2 (0.02)	59.7
Other Construction Occupations[c]		1,471	66.5	13.7 (0.01)	62.9
Non-Construction workers		97,669	67.5	16.2 (0.001)	59.6

BOC, US Bureau of the Census; SE, standard error.
[a]Available for 87% (n = 96,940) of eligible lung cancer cases. Details available in CCR (2008). It roughly corresponds to stage IIIb or IV of the TNM (tumor, node, metastases) classification [Mountain, 1997].
[b]Defined as having a 1990 BOC industry code of 060.
[c]Other Construction Occupations include tile setters (n = 106), carpet installers (n = 103), drywall installers (n = 118), support occupations (n = 71), sales occupations (n = 29), mechanics and repairers (n = 147), sheet metal workers (n = 59), concrete and terrazzo finishers (n = 201), truck drivers (n = 56), and unknown construction occupation (n = 359).

TABLE III. Distribution of Control Cancers

Cancer site	SEER code[a]	Number of cases
Prostate	28010	204,594 (63%)
Colon	21041–21060	74,507 (23%)
Kidney	29020	21,026 (7%)
Brain	31010	10,432 (3%)
Testicular	28020	5,717 (2%)
Thyroid	32010	5,451 (2%)
Bone and joint	23000	972 (<1%)
Total		322,699

[a]Surveillance Epidemiology and End Results (SEER) ICD-O-3 code definitions are available at http://seer.cancer.gov/siterecode/icdo3.d01272003/.

cancer was highest in Asians. In each of the four-race/ethnicity groups, roofer was the occupation with the highest risk for total lung cancer and each of the histologic subtypes of lung cancer (data not shown). The risk for NSCLC was highest among Asian roofers (7 cases, MOR = 5.17, 95% CI = 1.5, 17.8) and Asian operating engineers (6 cases, MOR = 5.39, 95% CI = 1.3, 21.9), but these MOR estimates are based on small numbers.

The risk for the different histologic subtypes of NSCLC was elevated for almost all construction occupations, with managers/engineers and supervisors being the notable exceptions (Tables V and VII). For adenocarcinoma, the risks were highest among roofers, welders, and non-Hispanic blacks, especially among non-Hispanic black roofers (11 cases, MOR = 2.8, 95% CI = 1.1, 6.8) and non-Hispanic black welders (9 cases, MOR = 3.7, 95% CI = 1.3, 10). The risk of squamous cell carcinoma was highest among welders, roofers, laborers, and Asians. The NSCLC finding in Asian roofers was likely driven by their heightened risk for squamous cell lung cancer (4 cases, MOR = 11.0, 95% CI = 1.2, 100). The risk of large cell lung cancer was highest among roofers, operating engineers, non-Hispanic blacks, and non-Hispanic white roofers (16 cases, MOR = 3.0, 95% CI = 1.6, 5.9).

DISCUSSION

This study found that construction workers in California have a significantly elevated risk for lung cancer. The increased risk was present in all histologic subtypes of lung cancer, in all blue-collar construction occupations, and across all four race/ethnicity groups. Construction workers were also diagnosed, though modestly, at an earlier age, at a more advanced stage, and had a lower 3-year survival compared to non-construction workers. To our knowledge, this is the first study to compare the risk of lung cancer among workers in four different race/ethnicity groups. We are also unaware of any previous study that compared the risk of lung cancer across such a large number of construction occupations.

TABLE IV. Risk of Lung Cancer Among Construction Occupations by Lung Cancer Histologic Subtype

	All lung cancer[a]		NSCLC[b]		Small cell lung cancer		Other lung cancer[c]	
Occupation	N	MOR (95% CI)	N	MOR (95% CI)	N	MOR (95% CI)	N	MOR (95% CI)
All construction workers	13,268	1.57 (1.54, 1.61)	8,460	1.55 (1.51, 1.59)	1,770	1.69 (1.58, 1.80)	2,235	1.53 (1.45, 1.62)
Brickmasons	226	1.50 (1.27, 1.76)	144	1.49 (1.22, 1.83)	28	1.52 (0.95, 2.41)	35	1.38 (0.92, 2.08)
Carpenters	2,169	1.58 (1.49, 1.66)	1,340	1.53 (1.43, 1.63)	261	1.59 (1.36, 1.85)	415	1.65 (1.46, 1.87)
Electricians	970	1.34 (1.24, 1.44)	623	1.34 (1.21, 1.47)	117	1.33 (1.07, 1.66)	177	1.33 (1.11, 1.59)
Laborers	2,689	1.86 (1.77, 1.95)	1,780	1.91 (1.80, 2.03)	360	1.95 (1.70, 2.23)	414	1.66 (1.47, 1.88)
Managers and Engineers	1,029	0.90 (0.84, 0.97)	651	0.86 (0.79, 0.94)	132	0.92 (0.75, 1.12)	181	0.95 (0.80, 1.13)
Metalworkers	219	1.60 (1.35, 1.89)	136	1.47 (1.19, 1.82)	34	1.88 (1.21, 2.92)	34	1.59 (1.04, 2.44)
Operating Engineer	699	1.71 (1.55, 1.88)	458	1.76 (1.56, 1.98)	92	1.55 (1.20, 2.01)	106	1.62 (1.27, 2.07)
Painter	1,229	1.89 (1.76, 2.04)	762	1.88 (1.71, 2.06)	180	2.30 (1.89, 2.81)	219	1.72 (1.45, 2.03)
Plumber	909	1.69 (1.55, 1.83)	583	1.66 (1.50, 1.84)	135	2.05 (1.63, 2.56)	136	1.51 (1.22, 1.86)
Roofer	312	2.62 (2.25, 3.06)	201	2.44 (2.02, 2.95)	45	3.31 (2.15, 5.12)	47	2.57 (1.73, 3.82)
Supervisor	1,130	1.06 (0.99, 1.13)	708	1.01 (0.92, 1.10)	158	1.09 (0.90, 1.31)	186	1.10 (0.92, 1.30)
Welder	216	2.16 (1.81, 2.58)	132	2.10 (1.68, 2.63)	29	2.72 (1.64, 4.51)	43	1.97 (1.33, 2.93)
Other	1,471	1.62 (1.52, 1.73)	942	1.59 (1.47, 1.73)	199	1.77 (1.48, 2.12)	242	1.59 (1.36, 1.86)

MOR, morbidity odds ratio; NSCLC, non-small cell lung cancer; 95%CI, 95% confidence interval.
[a]All lung cancer includes NSCLC, small cell lung cancer, other lung cancer, and lung cancer of unknown histology.
[b]NSCLC includes adenocarcinoma, squamous cell carcinoma, large cell carcinoma, and unspecified NSCLC.
[c]Other lung cancer includes carcinoma not otherwise specified (n = 15,097), malignant carcinoid tumor (n = 1,714), mesothelioma (n = 58), and other miscellaneous cancers (n = 1,641).

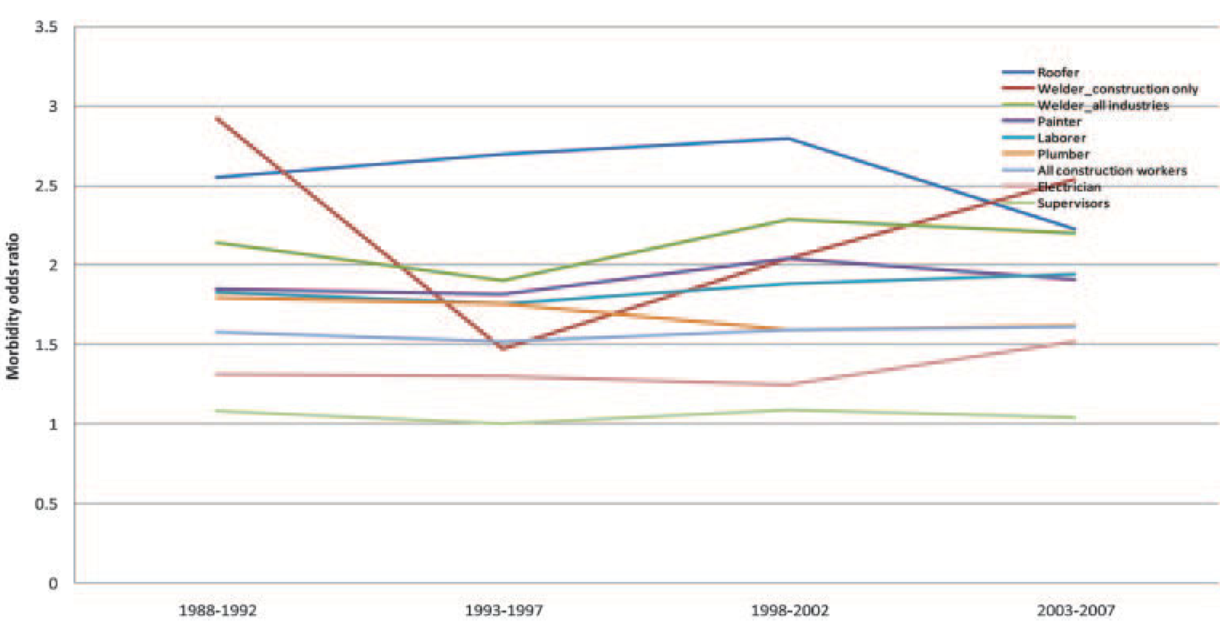
TABLE V. Risk of NSCLC Among Construction Occupations by NSCLC Histologic Subtype[a]

	Adenocarcinoma		Squamous cell lung cancer		Large cell lung cancer		Unspecified NSCLC	
Occupation	**N**	**MOR (95% CI)**	**N**	**MOR (95% CI)**	**N**	**MOR (95% CI)**	**N**	**MOR (95% CI)**
All construction workers	3,880	1.41 (1.35, 1.46)	3,095	1.70 (1.62, 1.79)	725	1.58 (1.43, 1.74)	760	1.78 (1.62, 1.95)
Brickmasons	61	1.34 (0.99, 1.83)	54	1.63 (1.16, 2.29)	15	1.40 (0.74, 2.65)	14	1.91 (0.98, 3.72)
Carpenters	582	1.33 (1.20, 1.47)	513	1.71 (1.52, 1.91)	123	1.56 (1.24, 1.95)	122	2.01 (1.59, 2.53)
Electricians	310	1.24 (1.09, 1.42)	202	1.34 (1.13, 1.59)	52	1.70 (1.20, 2.41)	59	1.63 (1.19, 2.24)
Laborers	788	1.70 (1.55, 1.85)	675	2.20 (1.98, 2.43)	148	1.81 (1.47, 2.24)	169	2.15 (1.77, 2.62)
Managers and Engineers	338	0.88 (0.77, 0.99)	198	0.80 (0.68, 0.94)	57	0.91 (0.67, 1.23)	58	0.98 (0.73, 1.32)
Metalworkers	69	1.73 (1.28, 2.34)	46	1.14 (0.81, 1.62)	8	0.97 (0.43, 2.19)	13	2.97 (1.40, 6.31)
Operating Engineer	204	1.51 (1.27, 1.79)	175	2.00 (1.64, 2.44)	45	2.38 (1.58, 3.60)	34	1.87 (1.22, 2.86)
Painter	351	1.83 (1.60, 2.10)	275	1.93 (1.65, 2.25)	65	1.46 (1.07, 1.98)	71	2.51 (1.84, 3.42)
Plumber	243	1.36 (1.16, 1.58)	254	2.06 (1.75, 2.43)	43	1.71 (1.16, 2.52)	43	1.84 (1.26, 2.68)
Roofer	97	2.51 (1.91, 3.30)	68	2.35 (1.70, 3.26)	19	3.03 (1.55, 5.91)	17	2.03 (1.10, 3.71)
Supervisor	341	0.97 (0.86, 1.10)	245	1.07 (0.92, 1.24)	63	1.19 (0.88, 1.60)	59	0.88 (0.66, 1.18)
Welder	62	1.84 (1.33, 2.53)	45	2.48 (1.66, 3.72)	6	1.25 (0.47, 3.36)	19	2.95 (1.60, 5.43)
Other	434	1.50 (1.34, 1.69)	345	1.74 (1.52, 1.99)	81	1.57 (1.19, 2.07)	82	1.59 (1.21, 2.08)

MOR, morbidity odds ratio; NSCLC, non-small cell lung cancer; 95%CI, 95% confidence interval.
[a]NSCLC includes adenocarcinoma, squamous cell carcinoma, large cell carcinoma, and unspecified NSCLC.

Strengths of Using California Data

There are several reasons why the CCR was chosen for this study. First, California is the most populous state in the country, which improves statistical power to detect associations. In addition, California has large numbers of Hispanics, Asians, and African Americans, which permitted us to assess risks among these racial and ethnic minorities. Second, we think the CCR has a high ascertainment rate because it is likely that few California residents leave



Numbers of lung cancer cases by year interval for some construction occupations				
All construction workers	3,747	3,473	3,311	2,737
Roofer	81	87	85	59
Welder	55	36	64	61
Supervisor	316	277	279	258

FIGURE 1. MORs for lung cancer among male workers in various construction occupations during four 5-year time intervals, California.

TABLE VI. Risk of Lung Cancer Among all Construction Workers by Race/Ethnicity and Lung Cancer Histologic Subtype

	All lung cancer[a]		NSCLC[b]		Small cell lung cancer		Other lung cancer[c]	
Race/ethnicity	Construction worker cases N	MOR (95% CI)	Construction worker cases N	MOR (95% CI)	Construction worker cases N	MOR (95% CI)	Construction worker cases N	MOR (95% CI)
All	13,268	1.57 (1.54, 1.61)	8,460	1.55 (1.51, 1.59)	1,770	1.69 (1.58, 1.80)	2,235	1.53 (1.45, 1.62)
Non-Hispanic whites	10,765	1.61 (1.57, 1.65)	6,736	1.57 (1.52, 1.62)	1,525	1.75 (1.63, 1.87)	1,843	1.58 (1.49, 1.68)
Non-Hispanic blacks	1,067	1.66 (1.53, 1.80)	749	1.75 (1.59, 1.93)	104	1.62 (1.25, 2.10)	158	1.31 (1.07, 1.60)
Hispanics	1,099	1.26 (1.17, 1.36)	731	1.26 (1.15, 1.38)	114	1.19 (0.95, 1.49)	185	1.28 (1.07, 1.53)
Asians	337	1.60 (1.39, 1.84)	244	1.56 (1.32, 1.84)	27	1.64 (1.00, 2.69)	49	1.85 (1.27, 2.7)

MOR, morbidity odds ratio; NSCLC, non-small cell lung cancer; 95%CI, 95% confidence interval.
[a]All lung cancer includes NSCLC, small cell lung cancer, other lung cancer, and lung cancer of unknown histology.
[b]NSCLC includes adenocarcinoma, squamous cell carcinoma, large cell carcinoma, and unspecified NSCLC.
[c]other lung cancer includes carcinoma not otherwise specified (n = 15,097), malignant carcinoid tumor (n = 1,714), mesothelioma (N = 58), and other miscellaneous cancers (n = 1,641).

the state in search of cancer diagnosis and treatment. California has many high quality hospitals and other cancer treatment facilities, and patients have little incentive to leave the state in pursuit of high quality care. Finally, the study can be considered population-based, because the CCR had statewide coverage for the years studied. Furthermore, it is organized regionally, consisting of 10 regions with six local offices. This gives the cancer registry a local presence and facilitates follow-up at the hospitals and other cancer reporting facilities in the region.

Limitations

Information on tobacco usage was unavailable, and therefore our findings could not be adjusted for smoking. In addition, only a qualitative measure of occupational exposure was available; i.e., longest held industry and occupation. We found that the elevations in risk of lung cancer among construction workers have changed little over the 20-year time period that was studied, despite the apparent decrease in lung cancer counts (Fig. 1). Due to our lack of data on smoking and workplace exposures, it is unclear how much of an effect smoking versus workplace carcinogen exposures had on these stable risks.

Information on industry and occupation were available only for 110,937 (59%) of the 187,862 male lung cancer cases between the ages of 18 and 97 years identified by the CCR between 1988 and 2007. Ascertainment bias would be present if the proportion of construction workers varied between those male lung cancer cases that were included versus excluded from the study. Furthermore, the I&O data available in medical records is not well standardized. I&O data are entered into the medical record through a variety of administrative or clinically based mechanisms by physicians, nurses, admitting clerks, and other hospital personnel. In addition, the purposes for collecting such information are often unrelated to identifying occupational exposures. When I&O data are present in the medical record, they may be incomplete, and from an uncertain time frame (i.e., it may be the current and not usual industry and occupation). Analyses of a large representative sample of US workers found moderate-to-high

TABLE VII. Risk of NSCLC Among all Construction Workers by Race/Ethnicity by NSCLC Histologic Subtype[a]

	Adenocarcinoma		Squamous cell lung cancer		Large cell lung cancer		Unspecified NSCLC	
Race/ethnicity	Construction worker cases N	MOR (95% CI)	Construction worker cases N	MOR (95% CI)	Construction worker cases N	MOR (95% CI)	Construction worker cases N	MOR (95% CI)
All	3,880	1.41 (1.35, 1.46)	3,095	1.70 (1.62, 1.79)	725	1.58 (1.43, 1.74)	760	1.78 (1.62, 1.95)
Non-Hispanic whites	3,075	1.41 (1.35, 1.48)	2,529	1.76 (1.67, 1.86)	572	1.61 (1.44, 1.80)	560	1.74 (1.56, 1.94)
Non-Hispanic blacks	314	1.61 (1.39, 1.87)	289	1.86 (1.58, 2.18)	67	1.79 (1.28, 2.49)	79	1.96 (1.45, 2.64)
Hispanics	371	1.29 (1.14, 1.46)	206	1.10 (0.93, 1.30)	68	1.30 (0.96, 1.76)	86	1.64 (1.25, 2.15)
Asians	120	1.28 (1.02, 1.60)	71	1.96 (1.43, 2.70)	18	1.29 (0.70, 2.35)	35	2.66 (1.66, 4.25)

MOR, morbidity odds ratio; NSCLC, non-small cell lung cancer; 95%CI, 95% confidence interval.
[a]NSCLC includes adenocarcinoma, squamous cell carcinoma, large cell carcinoma, and unspecified NSCLC.

levels of agreement between current/most recent job and longest-held job [Gómez-Marín et al., 2005]. As such, even if current employment information was the only available I&O data, it can serve as a reasonable surrogate for longest-held job. Error could also occur if the distribution of patients whose I&O data were collected is biased toward specific occupations and cancers, leading to over-representation of certain industries and occupations that fail to reflect the true distribution of these variables in the case and control group [Gilliland et al., 1997]; however, we have no evidence to suggest the presence of this bias. Finally, although 90 key words consistent with construction employment were used to identify construction workers in the entire CCR dataset, it is possible that some construction workers were miscoded to another industry. Because industry coding occurred before cases and controls were selected, the effect should be non-differential and would bias risk estimates towards the null.

This study involved inter-cancer comparisons. We took great care to eliminate from the control group cancers known to be associated with exposures occurring in construction. However, if it is subsequently determined that the control cancers are truly associated with construction industry employment, such misclassification could have attenuated our findings of excess risk. Despite the limitations of this study, the findings were generally consistent with the results of previous reports.

Histologic Subtypes of Lung Cancer Among Construction Workers

Consistent with data observed by SEER for other areas in the US, adenocarcinoma was the most common lung cancer histologic subtype in California [Spitz et al., 2006]. Although each of the major lung cancer histologic subtypes are related to tobacco-smoking exposure, the dominance of adenocarcinoma in the last three decades (compared to the dominance of squamous cell carcinoma in earlier decades) is thought related to the shift in the type of cigarette smoked since the 1950s, from unfiltered high-nicotine yielding cigarettes to filtered low-nicotine-yielding cigarettes [Spitz et al., 2006]. Those who smoke the latter type of cigarettes are thought to inhale more deeply, leading to heavier exposure of the distal airways, which is the common anatomic location for adenocarcinoma. The additives found in tobacco have also changed and this may also have contributed to the rise in adenocarcinoma [Alberg et al., 2007].

Several studies have examined the risk of lung cancer of various histologic subtypes among construction workers. However, we are aware of no other study that examined these risks in as many construction occupations as ours. The findings from these previous studies were not always consistent, and this may have been due to small sample sizes in some studies, differences in methodology, and differences in workplace exposures across the studied populations. Pukkala et al. [2009] performed a very large study of workers in Nordic countries who developed cancer between 1961 and 2005, and identified 208,297 lung cancer cases. Like ours, their analyses did not control for smoking. Pukkala et al. [2009] found significantly elevated standardized incidence ratios (SIRs) for all histologic subtypes examined (i.e., adenocarcinoma, squamous cell carcinoma, small cell carcinoma, and ‘‘other types’’) among plumbers, welders, painters, brick layers, and ‘‘other construction workers’’. Unlike our findings, they did not find any lung cancer elevations among electrical workers or wood workers. Pukkala et al. [2009] reported findings for occupation only, and not by industry. As such, it is likely that some workers in these occupations were employed in non-construction industries (e.g., welders are found in many different industries).

Other studies controlled for smoking, but their findings were not always consistent. For example, among smoking- and age-adjusted case–control studies, one found that Turkish construction workers had a significantly increased risk for adenocarcinoma [Elci et al., 2003], while in contrast, two other studies, one in Argentina and the other in Canada, found that construction workers had a significantly increased risk for squamous cell carcinoma [Pezzotto and Poletto, 1999; MacArthur et al., 2009]. In two of these studies [Pezzotto and Poletto, 1999; Elci et al., 2003], only seven construction workers had the histologic subtype at elevated risk (MacArthur et al. did not report these numbers).

Our study found that carpenters had a significantly increased risk for all histologic subtypes examined. Among smoking-adjusted studies of carpenters, Pezzotto and Poletto found a significantly elevated risk for adenocarcinoma, while MacArthur et al. found a significantly increased risk for squamous cell carcinoma. Siemiatycki [1991] also found that carpenters had significantly increased smoking-adjusted risks for squamous cell carcinoma. A smoking-adjusted case–control study in Uruguay involving 270 male lung cancer patients found significantly increased risks for squamous cell carcinoma among brickmasons, but did not find any significantly increased risks for small cell lung cancer or adenocarcinoma among brickmasons [De Stefani et al., 1996], which are findings similar to ours. Siemiatycki [1991] found that plumbers had a significantly increased smoking-adjusted risk for small cell carcinoma, as was found in our study, but in contrast to our study did not find significantly increased risks for adenocarcinoma or squamous cell carcinoma among plumbers. In contrast to Pukkala et al. but similar to our findings, MacArthur et al. [2009] found that electrical workers had significantly increased smoking-adjusted risks for small cell and large cell carcinoma.

Lung Cancer Among Roofers, Welders, and Painters

We found that roofers had the highest risk of lung cancer. Roofers can be exposed to bitumens (asphalt and/or coal tar pitch), asbestos and fiberglass. Very few previous studies of roofers were identified [Hammond et al., 1976; Menck and Henderson, 1976; Dong et al., 1995; De Stefani et al., 1996; Swaen and Slangen, 1997]. All found elevated risks for lung cancer, but only one was statistically significant (standardized mortality ratio, SMR = 4.96, $P < 0.01$) [Menck and Henderson, 1976]. When the results of various studies of roofers were pooled, roofers were found to have a significantly increased risk for lung cancer [Partanen and Boffetta, 1994; Bosetti et al., 2007], although these risk estimates (1.26 and 1.8, respectively) were lower than the risk we observed (MOR = 2.62). We found that welders had the second highest risk when all lung cancer was combined. Several other studies have also found significantly increased risks of lung cancer among welders ranging between 1.35 and 1.68 [Siemiatycki, 1991; Keller and Howe, 1993; Sorensen et al., 2007]. Welders have exposure to hexavalent chromium and nickel fumes [IARC, 1990; Keller and Howe, 1993]. The International Agency for Research on Cancer (IARC) classifies both hexavalent chromium and nickel exposures as carcinogenic to humans (Group 1), based on studies of non-welders (i.e., chromate production and plating workers, and nickel refining workers [IARC, 1990]. IARC [1990] concluded that welding fume exposure was possibly carcinogenic to humans (group 2B). Significantly increased risks for lung cancer have been observed among painters in several studies, including ours, ranging between 1.18 and 2.00 [Matanoski et al., 1986; Zahm et al., 1989; Burns and Swanson, 1991; Pukkala et al., 2009]. IARC [1989] concluded that occupational exposures experienced by painters are carcinogenic (Group 1). Painters are exposed to many different known or suspected carcinogens, including paints, asbestos, lead and solvents.

Race and Lung Cancer

We found that the risk of lung cancer was highest among non-Hispanic blacks, followed by non-Hispanic whites, Asians, and Hispanics. In a prospective cohort study of men and women in California and Hawaii, lung cancer rates were also found to vary by race/ethnicity, with rates highest in blacks (264/100,000), followed by whites (158), Japanese Americans (121) and Latinos (79) [Haiman et al., 2006]. Haiman et al. [2006] found that the differences in lung cancer risk across race/ethnicity groups were greatest among current and former smokers who smoked less than one pack of cigarettes per day, with blacks having significantly elevated risks compared to whites, Latinos, and Japanese Americans. However, no difference in lung cancer risk across race/ethnicity groups was found among current and former smokers who smoked more than 30 cigarettes per day. Haiman et al. [2006] speculated that the increased risk observed among blacks at lower levels of smoking was either because of differences in smoking behavior among blacks (e.g., blacks may inhale tobacco smoke more deeply and more frequently) or that blacks may be more susceptible to the effects of tobacco carcinogens at lower levels of smoking. With heavier smoking, any protective metabolic or other relevant pathways present in non-blacks may become saturated, resulting in relatively equal lung cancer risks across race/ethnicity. Interestingly, we found that for several occupations (i.e., welders, roofers, painters, plumbers, operating engineers, carpenters, electricians, and laborers), the relative risk of lung cancer was higher among non-Hispanic whites compared to non-Hispanic blacks (data not shown).

Role of Cigarette Smoking

Smoking causes lung cancer, and it has been shown that smoking rates are higher among construction workers compared to all workers combined [Lee et al., 2004]. However, it is reasonable to assume that the magnitude of many of the lung cancer MORs found in our study are unlikely explained by smoking alone. MORs >1.2 for diseases strongly related to smoking are likely influenced by other exposures in addition to tobacco [Steenland et al., 1984]. Additionally, selected construction occupations with a similar national smoking prevalence had different lung cancer MORs. For example, the national smoking prevalence of supervisors (36.4%), plumbers (33.8%), and electricians (32.8%) was found to be similar [Lee et al., 2004]. However, the risk of lung cancer was significantly elevated among plumbers (MOR = 1.69) and electricians (MOR = 1.34) but not among supervisors (MOR = 1.06). It should be noted that this comparison does not take into account smoking intensity, and it is possible that our findings may have arisen because plumbers and electricians were heavier smokers compared to supervisors. This comparison also does not take into account that these workers were from California, where smoking prevalence and lung cancer mortality are lower compared to the rest of the country. Smoking prevalence in California was higher than the rest of the US in the 1960s, but has been lower than the rest of the US since 1971 [Pierce et al., 2010]. The prevalence of smoking is declining faster in California compared to the rest of the US and is predicted to be half that of the rest of the US by 2010 (9.3% in California vs. 17.8% in the rest of the US). These smoking reductions in California are thought to have resulted from aggressive imposition of cigarette excise taxes, adoption of the first statewide comprehensive tobacco program in 1988, and adoption of the first statewide smokefree workplace law in 1994 [Pierce et al., 2010]. Unfortunately, we do not know if these smoking reductions are uniform across the California workforce, or if construction workers are more likely to initiate smoking and less likely to quit compared to other California workers.

Carcinogenic Exposures Experienced by Construction Workers

Silica, asphalt fumes, PAHs, diesel exhaust, paints, asbestos, lead, metal fumes, and solvents are among the known or suspected carcinogen exposures experienced by construction workers [Järvholm, 2006]. Unfortunately, we are not aware of systematic surveillance of occupational exposures. Therefore, it is difficult to determine if the nature and extent of these carcinogenic exposures is changing over time.

Access to Health Care

Our findings may in part be due to some unfavorable sociologic characteristics among construction workers. The National Health Interview Survey (NHIS) collects data on the civilian non-institutionalized population of the United States using a multi-stage clustered sample design that produces nationally representative estimates. According to NHIS data collected in 2010, construction workers employed in the week preceding interview, when compared to all individuals employed in the week preceding interview, were less likely to have health insurance (45% of construction workers vs. 83% among all workers have health insurance), less likely to have paid sick leave (24% vs. 55%) and less likely to have a usual place to receive health care (70% vs. 81%; NHIS, unpublished 2010 data). These characteristics could lead to delays in lung cancer diagnosis and suboptimal treatment.

Age at Diagnosis

We found only one other study that reported the mean age of diagnosis of lung cancer among construction workers [Keller and Howe, 1993]. Like our study, Keller and Howe found that construction workers were younger at diagnosis than others with lung cancer.

CONCLUSION

Construction workers in general and nearly every specific blue-collar construction occupation that was examined were found to have a significantly elevated risk for all lung cancer combined and for each of the specific lung cancer histologies. Roofers and welders had the highest lung cancer risks. Construction workers in each of the four-race/ethnicity groups also had significantly increased lung cancer risks. The excess risks for lung cancer among construction workers appear little changed over time. Our analyses found that construction workers were diagnosed at an earlier age, at a more advanced stage, and had lower 3-year survival, though the differences were modest. The construction industry should be encouraged to develop or improve policies to reduce carcinogen exposures. In addition, construction workers should be encouraged to quit smoking.

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