Occupational Risks of Bladder Cancer in the United States: I. White Men

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We examined the relationship between occupation and bladder cancer risk using data obtained from interviews conducted with 2,100 white males with bladder cancer and 3,874 population controls during the National Bladder Cancer Study, a population-based, case-control study conducted in 10 areas of the United States. The strongest evidence of increased risk among white men was observed for painters, truck drivers, and drill press operatives. For painters, the overall relative risk was 1.5 [95% confidence intervals (CI) = 1.2-2.0]. Among painters who started working prior to 1930, a significant trend in risk with increasing duration of employment as a painter was apparent; the relative risk for such painters employed 10 or more years was 3.0. For truck drivers and drill press operatives, overall risks were 1.3 (CI = 1.1-1.4) and 1.4 (CI = 0.9-2.1), respectively. We observed a significant, positive trend in risk with increasing duration of employment in each of these occupations, with relative risks peaking at approximately two for long-term workers. Excess risks were also observed for workers in several other occupations. In all, we estimate that 21%-25% of bladder cancer diagnosed among white men in the United States is attributable to occupational exposures. [J Natl Cancer Inst 81:1472-1480, 1989]

The relation between occupation and bladder cancer risk, one of the most well-studied areas in occupational cancer epidemiology, remains unclear. During the last three decades, results of various studies have suggested approximately 40 occupations in which workers could be at increased risk of bladder cancer. Most of these findings have two characteristics in common. First, relative risks (RRs) are usually less than 2.0 and the number of exposed subjects is small. Second, they are typically equivocal results, confirmed by some studies and not by others.

Data from the National Bladder Cancer Study, the largest study of occupation and bladder cancer conducted to date, provided us with the opportunity to examine associations suggested in previous studies, but our risk estimates were often based on larger numbers of subjects than those typically found in case-control studies. Our purpose was also to identify new high-risk occupations.

Materials and Methods

The case series consisted of all histologically confirmed cases of carcinoma of the urinary bladder first diagnosed during a one-year period that began in late 1977 among residents aged 21 to 84 years from 10 geographic areas, i.e., the states of New Jersey, Connecticut, Iowa, New Mexico, and Utah, and the cities of Atlanta, Detroit, New Orleans, San Francisco, and Seattle.

The control series was drawn from the general population of the study areas. Cases and controls were frequency-matched for age (within 5 yr) and geographic area. Approximately two controls were selected for each case. Controls 21-64 years old were chosen by a method of random digit dialing (*1*). Controls 65-84 years old consisted of a stratified random sample drawn from the Health Care Financing Administration's lists of the population over 64 years old for each study area.

Interviews were usually conducted in the subjects' homes by a trained interviewer within 3 months of diagnosis. Of the males identified for study, we interviewed 75% of the cases, 84% of the controls aged 21-64 years, and 83% of the controls aged 65-84 years. For more detailed information regarding response rates, *see* (*2*).

The questionnaire was designed to elicit detailed information on every job a subject had held for at least 6 months since the age of 12 years. Industry and job title were coded according to the U.S. Bureau of the Census alphabetical index of industries and occupations (*3*). We then applied a two-step process to make our analyses more exposure ori-

Received April 3, 1989; revised June 22, 1989; accepted July 27, 1989.

Sponsored by the U.S. Food and Drug Administration; the National Cancer Institute, National Institutes of Health; and the Environmental Protection Agency.

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We thank Drs. Sholom Wacholder and Jay Lubin, Patricia Stewart, and John Fajen for information and assistance; Meg Seldin, Alan Stewart, Robina Thornton, and Thomas Helde for data processing; and Jennifer Donaldson, Susan Privot, Holly Brown, and Robert Garcon for clerical assistance. We also thank the collaborating principal investigators on the National Bladder Cancer Study: Drs. Ronald Altman, Donald Austin, Kenneth Cantor, Margaret Child, Charles Key, Loraine D. Marrett, Thomas J. Mason, J. Wister Meigs, Max H. Myers, Ambati Narayana, J. W. Sullivan, G. Marie Swanson, David Thomas, and Dee West.

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ented. First, workers within each industry were grouped by occupational code. Second, occupational codes were grouped by potential for similar exposure. For example, checkers, examiners, inspectors, and graders within the rubber products manufacturing industry were grouped together because they probably have similar exposures but very different census codes that reflect their varying levels of skill. In all, we transformed 417 census codes into 163 occupational categories that were meaningful for analysis. We also used a second approach, grouping all workers involved in processing within a specific industry into a single category (referred to as "processing" occupations). The latter approach proved especially useful for several occupations, such as "petroleum processing worker." Despite efforts to make our analyses exposure oriented, however, some random misclassification of exposure may have occurred and biased estimates of RR toward the null value.

The association between employment in a particular occupation and bladder cancer risk was measured by the RR as estimated by the odds ratio. In all such computations, risk associated with employment in each occupation was estimated relative to the risk for subjects "never employed" in that occupation. Adjusted RRs were estimated by the maximum likelihood method (*4*). The data were initially stratified by age, smoking, employment in other high-risk occupations, geographic area, education, source of drinking water, and birthplace. Smoking (in five categories) was the only factor for which adjustment had a consistent impact on the estimates of RR; thus, all RRs are adjusted for smoking. As indicated in the tables, they are also adjusted for any additional factor that had a confounding effect on the point estimate for a specific occupation. However, little confounding was identified in these data. Two-sided 95% confidence intervals (CI) for the adjusted RR estimates were computed by Gart's interval estimation procedure (*4*). An increased or decreased risk was considered statistically significant when the null value was not included in the 95% CI. One-tailed significance tests for trend were computed by the Mantel extension of the Mantel-Haenszel procedure (*5*). Population attributable risks (PARs) were computed by the method of Whittemore (*6*) and were adjusted for age, geographic area, and smoking. Two-sided 95% CI for the adjusted PAR were also calculated according to Whittemore (*6*).

Because a large number of occupations have been included in this analysis, all results from this study cannot be presented. Thus results are given for occupation categories in which at least 15 men had worked and that satisfied at least one of the following criteria: (*a*) any occupation category in which workers experienced a statistically significant increased or decreased risk, (*b*) any a priori suspect occupation category in which workers had an RR of at least 1.3, regardless of statistical significance, (*c*) any occupation category in which workers had an RR of at least 1.5, or less than or equal to 0.6, regardless of statistical significance, or (*d*) any occupation that was a summary category. In a few instances, results are also presented for an a priori suspect occupation of special interest that did not satisfy these criteria. Sixty of 163 occupation categories fulfilled at least one of these criteria.

Results

This occupational analysis was based on 2,100 white male cases and 3,874 white male controls. Table 1 shows that controls were similar to cases with regard to a number of descriptive occupation factors, including total number of years employed, age at initial employment, number of industries, number of occupations, and number of jobs ever held.

A Priori Suspect Occupations

In table 2, RRs for all a priori suspect occupations are shown. In general, those with summary categories are presented first, with subcategories for which workers had an RR of at least 1.3 or 0.6 or less. These are followed by some miscellaneous specific occupations that did not fit easily into a summary category.

Painters had an overall 50% excess risk. Elevations were apparent for three of the four subgroups of painters (i.e., those in construction and maintenance, painters of manufactured articles, and artistic painters), although painters in construction and maintenance were the only ones who experienced a significantly increased risk. In contrast, sign painters experienced little excess risk (RR = 1.1, CI = 0.3-3.7). Among nonsmokers, the RR for all painters was 1.4.

A significant elevation in risk was also observed for the summary category of motor vehicle drivers. These results have been presented in detail elsewhere (*7*).

The summary category of railroad workers had an overall RR of 1.3. This excess was attributable to elevations in three subgroups of railroad workers: mechanics and repairmen, conductors, and switchmen. None of these excesses were statistically significant, however.

For the summary category of mechanics, the RR was 1.2, which was not significant. Auto mechanics employed in the trucking services industry had an RR of 10.2, which was significant (CI = 2.1-68.6).

Nonsignificant excess risks were also observed for two subgroups of metal machinery workers, primary aluminum processing workers, and five subgroups of metalworkers. Most of the excesses were small, ranging from 1.3 to 1.5, with the exception of blacksmiths and metal heaters, for whom the RRs were higher but were based on fewer numbers of exposed subjects. In addition, metal machinery workers who were employed specifically in the machinery manufacturing industry had a significantly elevated risk (RR = 2.9, CI = 1.1-7.8). In contrast, riveters and fasteners, a subgroup of metalworkers, experienced a significant decreased risk.

Table 1. Comparison of cases and controls by employment patterns, white males

Occupation factor	Mean values	
	Cases	Controls
No. of years employed	44.6	44.2
Age at initial employment	16.7	16.6
No. of industries	4.6	4.4
No. of occupations	5.4	5.1
No. of jobs	7.7	7.3
No. of subjects	2,100	3,874

Table 2. No. of cases and controls ever employed in each a priori suspect occupation category and RRs, white males

Occupation title	Cases*	Controls*	RR†	95% CI
Summary printer	37	77	0.8	0.5-1.2
Summary painter	116	138	1.5	1.2-2.0
Painter, construction and maintenance	76	86	1.5	1.1-2.2
Painter, manufactured articles	25	34	1.3	0.8-2.3
Artistic painter	13	13	1.8	0.8-4.3
Summary driver of motor vehicles	556	845	1.2	1.1-1.4
Bus driver	49	75	1.2	0.8-1.8
Truck driver or deliveryman	488	742	1.2	1.0-1.4
Taxicab driver, chauffeur	77	92	1.5	1.1-2.0
Summary railroad worker	57	74	1.3	0.9-2.0
Railroad mechanic, repairman	17	24	1.3	0.7-2.6
Railroad conductor	7	6	1.4‡	0.4-4.9
Railroad switchman	13	11	2.0	0.8-4.9
Summary mechanic	353	533	1.2	1.0-1.4
Auto mechanic in trucking service industry	11	2	10.2	2.1-68.6
Summary metal machinery worker	477	755	1.1	1.0-1.3
Machinist	102	144	1.3	1.0-1.7
Drill press operative	51	59	1.4§	0.9-2.1
Primary aluminum processing worker	12	15	1.5	0.6-3.5
Summary welder and solderer	88	151	1.0	0.7-1.3
Summary ore refining and foundry worker	37	67	1.0	0.7-1.5
Summary metal working and fabrication	255	401	1.2	1.0-1.4
Forgeman, hammerman, roller, finisher	11	13	1.4	0.6-3.4
Blacksmith	7	6	2.4	0.7-8.2
Heaters, metal	5	4	1.9¶	0.4-8.7
Filer, polisher, sander, and buffer	53	65	1.5	1.0-2.2
Riveter and fastener	8	36	0.4	0.2-0.9
Structural metal worker	12	15	1.4	0.6-3.3
Summary hairdresser and barber	28	37	1.3	0.8-2.3
Hairdresser	7	4	2.8	0.7-11.6
Summary construction worker	292	504	1.0	0.9-1.2
Cement and concrete finisher	10	9	1.9**	0.8-4.9
Inspector, grader, weigher, construction foreman	47	54	1.6	1.1-2.5
Summary petroleum processing worker	71	103	1.3	1.0-1.8
Petroleum processing worker, crude extraction	16	12	2.4	1.1-5.5
Petroleum processing worker, refining	39	58	1.3	0.8-2.0
Petroleum processing worker, products	22	35	1.2	0.7-2.1
Summary salesman and sales manager	422	769	1.0	0.9-1.2
Summary lumberman and woodworker	213	313	1.3	1.0-1.5
Carpenter	148	199	1.4	1.1-1.8
Lumberman	37	43	1.5	0.9-2.4
Summary paper processing worker	30	48	1.1	0.7-1.9
Miscellaneous paper and pulp products worker	10	13	1.3	0.5-2.3
Summary cook, baker, food counter worker	144	211	1.2	0.9-1.5
Food counter and fountain worker	48	60	1.4	0.9-2.1
Summary food service worker	133	258	0.9	0.7-1.1
Miscellaneous a priori suspect occupations				
Dyer	7	21	0.6	0.2-1.4
Textile worker	38	111	0.6	0.4-0.9
Rubber processing worker	28	36	1.3	0.8-2.2
Leather processing worker	13	18	1.2	0.6-2.7
Chemical processing worker	58	85	1.2	0.8-1.7
Roofer and slater	10	10	1.7	0.6-4.4
Stationary engineer	40	47	1.4	0.9-2.3
Stationary fireman or furnace operator	57	80	1.3	0.9-1.9
Butcher in meat products manufacturing industry	13	17	1.5	0.7-3.4
Asbestos and insulation worker	7	7	1.9**	0.7-5.3

*Values indicate No. of males who were ever employed in each occupation.

†Risk is given for workers in each occupation, relative to a risk of 1.0 for males never employed in that occupation. Smoking-adjusted RRs are given in every instance, unless otherwise specified.

‡Adjustment was made for smoking and employment in other high-risk occupations.

§Adjustment was made for smoking and geographic area.

¶Adjustment was made for geographic area.

**Adjustment was made for smoking and education.

Hairdressers and barbers experienced a nonsignificant increased risk. This finding, however, was mostly due to an RR of 2.8 for a small number of hairdressers.

Although no overall increased risk was observed for construction workers, two subgroups of construction workers experienced elevated risks; cement and concrete finishers had an RR of 1.9, which was not significant, and inspectors, graders, weighers, and construction foremen had an RR of 1.6, which was significant.

For petroleum processing workers, a 30% excess in the overall risk was observed. This elevation was due primarily to increased risks apparent for men who worked in crude extraction (RR = 2.4) and in refining (RR = 1.3).

Increased risk was also apparent for lumbermen and woodworkers, mainly attributable to a significant 40% increased risk among carpenters and a nonsignificant 50% increased risk among lumbermen. Lumbermen and woodworkers who never smoked or smoked less than one pack per day had an RR of 2.2.

Risk was also estimated for processing workers in the manufacture of paper and allied products. Little overall excess risk was apparent for this occupational group, although processing workers involved in the manufacture of miscellaneous paper and pulp products experienced a nonsignificant increased risk (RR = 1.3).

For the summary category of cooks, bakers, and food counter workers, a small nonsignificant increased risk was observed. This excess was partly attributable to a nonsignificant elevation for food counter and fountain workers (RR = 1.4). No increased risk was found among food service workers, however.

Table 2 also contains a group of miscellaneous a priori suspect occupations, which have been previously reported to be associated with increased risk, but were typically based on small numbers of subjects. Our data, usually based on larger numbers, document small nonsignificant elevations in risk for rubber processing workers, roofers and slaters, stationary engineers, stationary firemen or furnace operators, butchers in meat products manufacturing, and asbestos and insulation workers. Our data are also supportive of small increased risks for leather processing and chemical processing workers that have been examined in detail in (*8,9*). Men employed in the production of organic chemicals, in particular, had an RR of 1.3 (*9*). In contrast with reports from some previous studies, we observed a significantly decreased risk for textile workers and a nonsignificantly decreased risk for dyers.

A Posteriori High- and Low-Risk Occupations

Occupations not previously suggested as high risk in which workers had an increased RR that was either statistically significant or 1.5 or greater in magnitude are presented in table 3. Statistically significant elevations were observed for three occupations: produce grader and packer; salesman of service and construction; and checker, examiner, and inspector in manufacturing. Nonsignificant increased risks were apparent for bootblack; funeral director and embalmer; blaster and powderman; agricultural scientist; gardener in horticultural services; writer, radio/television announcer and entertainer; telephone and telegraph operator; assessor and controller; and architect.

Men in five occupational groups had decreased RRs, i.e., statistically significant decreased RRs and/or RRs of 0.6 or less (table 3). Baggage porters, biological scientists, and computer specialists experienced significantly decreased risks, and actors, athletes and dancers, and editors and reporters experienced nonsignificant decreased risks.

Temporal Factors

We examined the relationship between bladder cancer risk and duration of employment for each occupation category

Table 3. No. of cases and controls ever employed in each a posteriori high- and low-risk occupation category* and RRs, white males

Occupation title	Cases†	Controls†	RR‡	95% CI
A posteriori high-risk occupations				
Bootblack	13	12	1.9	0.8-4.4
Funeral director, embalmer	4	5	1.6	0.4-7.2
Produce grader and packer	9	5	3.2§	1.1-9.3
Salesman of service and construction	24	22	2.2	1.2-4.1
Blaster and powderman	21	19	1.7	0.9-3.3
Checker, examiner, inspector, manufacturing, NEC	132	181	1.4	1.1-1.8
Agricultural scientist	10	15	1.5§	0.6-3.7
Gardener in horticultural services industry	23	28	1.7	0.9-3.0
Writer, radio/television announcer, entertainer, NEC	21	26	1.5	0.8-2.7
Telephone and telegraph operator	17	18	1.9	0.9-4.0
Assessor and controller	42	59	1.5§	1.0-2.3
Architect	8	11	1.8§	0.7-4.8
A posteriori low-risk occupations				
Baggage porter	5	27	0.3	0.1-0.9
Actor, athlete, dancer	12	32	0.6	0.3-1.3
Editor, reporter	10	30	0.6	0.3-1.4
Biological scientist	9	46	0.4	0.2-0.9
Computer specialist	7	40	0.3	0.1-0.8

* *See* Materials and Methods section for definition. NEC = not elsewhere classified.

† Values indicate No. of males who were ever employed in each occupation.

‡ Risk is given for workers in each occupation, relative to a risk of 1.0 for males never employed in that occupation. Smoking-adjusted RRs are given in every instance, unless otherwise specified.

§ Adjustment was made for smoking and education.

with an overall RR of at least 1.0. A significant positive trend in risk with increasing duration of employment was apparent for the 16 occupations shown in table 4. Of these, the trend was consistent, as well as significant, for eight occupations: drill press operative; lumberman; bootblack; food counter and fountain worker; salesman of service and construction; blaster and powderman; writer, radio/television announcer, entertainer; and telephone and telegraph operator.

The relationship between initial year of employment and risk was examined for all occupational groups for whom the overall RR was elevated or a significant trend in risk with increasing duration of employment was apparent. Three provocative observations emerged from these analyses. The overall increased risks for railroad mechanics and petroleum processing workers were apparent only for those who began their employment prior to 1930 (RR = 2.1 and 8.1, respec-

Table 4. No. of cases and controls and RRs, according to duration of employment in specified occupation, white males*

Occupation title	Duration (yr)	Cases	Controls	RR†	Trend test (*P*)
Summary painter	<5	50	56	1.7	.001
	5-9	14	28	0.9	
	10-24	26	28	1.6	
	25+	22	21	1.9	
Truck driver or deliveryman	<5	208	379	1.0	<.001
	5-9	102	148	1.3	
	10-14	58	65	1.7	
	15-24	59	52	2.1	
	25+	54	88	1.1	
Taxicab driver, chauffeur	<5	44	48	1.7	.017
	5-9	14	26	0.9	
	10+	16	15	1.9	
Drill press operative	<5	22	33	1.0‡	.008
	5-9	15	14	1.8‡	
	10+	12	9	2.4‡	
Filer, polisher, sander, and buffer	<5	36	38	1.8	.013
	5-9	5	17	0.5	
	10+	12	8	3.0	
Inspector, grader, weigher, construction foreman	<5	14	16	1.6	.048
	5-9	16	15	1.9	
	10-19	7	16	0.8	
	20+	8	7	2.2	
Checker, examiner, inspector, manufacturing, NEC	<5	57	79	1.4	.001
	5-9	30	42	1.4	
	10-14	15	22	1.4	
	15-24	11	22	1.0	
	25+	18	10	3.7	
Manufacturing laborer, NEC	<5	150	243	1.1	.012
	5-9	49	68	1.3	
	10-19	29	35	1.5	
	20+	13	18	1.3	
Lumberman	<5	19	25	1.3	.032
	5+	17	16	1.8	
Bootblack	<5	8	10	1.3	.026
	5+	5	2	4.8	
Stationary fireman or furnace operator	<5	22	48	0.8	.036
	5-9	19	9	3.8	
	10+	13	20	1.2	
Food counter and fountain worker	<5	32	43	1.4	.013
	5+	16	15	1.9	
Salesman of service and construction	<5	9	10	1.6	.004
	5-14	5	6	1.6	
	15+	10	6	3.2	
Blaster and powderman	<5	14	16	1.5	.018
	5+	7	3	3.3	
Writer, radio/television announcer, entertainer, NEC	<5	7	16	0.7	.019
	5+	14	9	3.0	
Telephone and telegraph operator	<5	7	9	1.4	.026
	5+	10	9	2.3	

*Males with unknown duration of employment were excluded.

†Risk is given for workers in each level of duration of employment in the specified occupation, relative to a risk of 1.0 for males never employed in that occupation; adjustment was made for smoking and age.

‡Adjustment was made for geographic area.

tively), and the increased risk for primary aluminum processing workers was limited to men who began working in 1950 or later (RR = 2.5).

The joint effect of duration and initial year of employment was examined for all occupations in which either the overall RR was elevated or the trend in risk with duration of employment was significant. Table 5 shows that, although no consistent trend with increasing duration was observed for painters (table 4), a consistent trend was apparent among those first employed prior to 1930. The RR for painters who started working before 1930 and were employed 10 or more years was 3.0.

As noted elsewhere (*7*), examination of the joint effect of duration and initial year of employment as a truck driver revealed that truck drivers who started working before 1930 experienced a consistent significant trend in risk with increasing duration of employment. The RRs for such truck drivers by duration were: less than 5 years, 1.2; 5-9 years, 1.4; 10-24 years, 2.1; 25+ years, 2.2.

For drill press operatives, the consistent positive trend in risk with increasing duration observed in table 4 was only apparent among those men first employed prior to 1950 (<5 yr duration: RR = 0.9, 5+ yr duration: RR = 1.7). For drill press operatives first employed in 1950 or later, the risk was elevated for both long- and short-term workers (<5 yr duration: RR = 2.8; 5+ yr: RR = 2.9).

Population Attributable Risks

The PARs for occupation are shown in table 6. A fundamental problem for investigators in estimating the PAR for occupation is defining occupational risk. Our approach was to estimate the PARs for occupation using a variety of definitions and to present the range of these estimates. Our lowest estimate was based on defining occupational risk as employment in any a priori suspect occupation with an RR of at least 1.1. A priori suspect occupations with RRs of less than 1.1 were excluded because such occupational exposures did not explain any excess risk in our data. A slightly higher estimate of the PAR was achieved when we combined employment in an a priori suspect occupation and that in any occupation with an RR of at least 1.5 or a significant duration effect. In white men, the PAR for occupation was 21% and 25%, respectively, under these two definitions. In addition, the PAR varied by age; men under 65 years had the highest, ranging from 31% to 35%, whereas those aged 65-74 years had the lowest, ranging from 9% to 10%.

Table 5. RRs* and No. of cases and controls according to initial year of employment and duration of employment as a painter, white males†

Starting year	RR for duration (yr)‡		
	<5	5-9	≥10
<1930	1.2 (10,16)	1.3 (5,7)	3.0 (18,11)
1930-1939	1.5 (8,11)	0.4 (2,9)	1.5 (9,10)
≥1940	2.0 (32,29)	1.0 (7,12)	1.4 (21,28)

*Risks are relative to a risk of 1.0 for males never employed as a painter; adjustment was made for smoking and age.

†Males with unknown initial year of employment and/or duration of employment were excluded.

‡First number in parentheses indicates No. of cases, the second indicates No. of controls.

Table 6. PARs (%)* for occupation by age, white males

Age (yr)	Ever employed in an a priori suspect occupation†	95% CI	Ever employed in a high-risk occupation‡	95% CI
21-64	31	20 to 44	35	22 to 51
65-74	9	−10 to 27	10	−11 to 30
75-84	23	9 to 46	28	13 to 50
Total	21	13 to 32	25	16 to 36

*PARs were adjusted for age, area, and smoking.

†Only a priori suspect occupations with an RR of at least 1.1 were included.

‡A high-risk occupation was defined as either an a priori suspect occupation with an RR of at least 1.1 or any occupation with an RR of at least 1.5 or a significant duration-response relationship.

Discussion

The large number of comparisons in this analysis makes it virtually certain that some of the observed increased and decreased bladder cancer risks are chance occurrences. The decreased risks are more likely due to chance than the increased risks because it seems implausible that many occupational exposures reduce cancer risk (*10*).

Regarding the observed increased risks, we carefully weighed the following five factors to distinguish true high-risk occupations from those effects that may be due to chance: (*a*) magnitude of risk, (*b*) statistical significance, (*c*) duration-response relationship, (*d*) consistency with results of previous epidemiologic studies, and (*e*) consistency with laboratory results.

Using these criteria, we concluded that the strongest evidence of increased risk among white men in these data is for painters, truck drivers, and drill press operatives.

For painters, the overall RR was 1.5 (CI = 1.2-2.0) from data based on 116 cases and 138 controls. Among painters who started working prior to 1930, there was a consistent and significant positive trend in risk with increasing duration of employment. For painters who started working before 1930 and were employed 10 or more years, the RR was 3.0.

An increased bladder cancer risk among painters has been observed in nine studies (*11-19*). The overall RR for employment as a painter in most of these studies was 1.2-1.5. Despite these numerous reports, the bladder cancer excess among this group of workers has received little attention, perhaps because most previous reports were based on small numbers of painters. Our findings, based on substantial numbers, indicate that this excess is probably real and should be pursued. Painters may have been exposed to many known or suspected carcinogens, including benzidine, polychlorinated biphenyls, formaldehyde, and asbestos in paints; and benzene, dioxane, and methylene chloride as solvents (*20*). Identification of the exposure responsible for this excess could be an

important next step in bladder cancer research, particularly because painting is not only a widespread vocation, but also a popular avocation.

Our results also indicated that men employed as truck drivers experienced increased bladder cancer risk. This finding is consistent with the results of two previous case-control studies that suggested exposure to motor exhausts is related to excess risk (*12,21*). The RR for truck drivers in our study was 1.2 when the unexposed group included men who were never employed as truck drivers. When the unexposed group was restricted to include only those men who were never occupationally exposed to motor exhaust, the RR increased to 1.3, which was statistically significant (*7*). For those truck drivers first employed at least 50 years prior to diagnosis, a consistent and significant positive trend in risk with increasing duration of truck driving was apparent. Of these, truck drivers employed 25 years or more had an RR of 2.2. Taxicab and bus drivers also experienced some excess risks. The increased bladder cancer risk among truck drivers and other motor vehicle drivers has been confirmed by results of seven subsequent studies conducted in various populations throughout the world (*17,19,22-26*). These findings and the experimental evidence of the mutagenicity and possible carcinogenicity of motor exhaust particulates suggest a role for motor exhaust exposure in human bladder carcinogenesis (*7*).

We also observed increased risks for two subgroups of metal machinery workers, machinists and drill press operatives, for whom the overall RRs were 1.3 and 1.4, respectively. Neither of the elevations was statistically significant, however.

Risk elevations among machinists have been reported in 16 previous studies (*14,18,19,21,25-36*); the RR estimates from most studies have been based on small numbers of exposed subjects. In some, excesses have been seen for particular types of metal machinery workers, such as tool and die makers (*18,28,31,32,37*), turners (*19,36*), blending machine operatives (*26*), and pressing machine operatives (*26*). In our data, the strongest evidence of increased risk among metal machinery workers was observed for drill press operatives. They experienced a consistent and significant positive trend in risk with increasing duration of employment; those employed 10 or more years had an RR of 2.5. The excess was apparent in long-term drill press operatives who started working before and after 1950. For short-term drill press operatives, the increased risk was restricted to those who started after 1950. This observation may reflect secular changes in exposure.

Drill press operatives, as well as other metal machinery workers, are exposed to cutting and lubricating oil mists used as coolants and lubricants in metal machining processes (*37,38*). Since World War II, there has been a shift from natural to synthetic cutting fluids (*39*). The difference in the carcinogenic effect of synthetic versus natural cutting oils on the bladder is largely unknown, although some synthetic cutting fluids contain nitrosamines (*39*). In the aggregate, these observations suggest that metal machinery workers have an increased risk of developing bladder cancer.

Elevations in risk were also observed for white men employed in many other a priori suspect occupations. No consistent or significant positive trends in risk with increasing duration of employment were apparent, however, for these occupations. Although most of these risks were low level, some of these findings are provocative, given the level of suspicion raised about them in previous studies. These include railroad, primary aluminum, petroleum, paper and pulp products workers, and roofer and slater.

Our study has also suggested previously unrecognized risks for workers in a number of occupations. The elevated risk observed for produce graders and packers, agricultural scientists, and gardeners in the horticultural services industry raise the question of whether certain pesticides or herbicides may be human bladder carcinogens. Bootblacks also appeared to have an elevated bladder cancer risk. Although not previously recognized in studies of bladder cancer, this excess is plausible in view of their heavy exposure to dyes in shoe polish. Our data also suggested that asbestos and insulation workers may have an increased bladder cancer risk. This observation was based on a small number of exposed subjects, however. Only one previous study (*40*) reported that asbestos-exposed workers experienced increased bladder cancer risk, although preliminary results from an ongoing case-control study in the area of Prato/Florence, Italy, indicate that workers with probable asbestos exposure may also have an increased bladder cancer risk (Seniori-Costantini A: personal communication). In addition, we identified a number of other high-risk occupations, such as salesman of service and construction, for which we reviewed questionnaires to determine specific exposures that may have been responsible for the observed excess. This effort, however, did not provide any additional information.

Our estimate of the PAR for occupation in white men ranged from 21% to 25%. Our lowest estimate was based on defining occupational risk as employment in any a priori suspect occupation with an RR of at least 1.1. A priori suspect occupations with RRs of 1.1-1.4 were included to avoid exclusion of true high-risk occupations with low point estimates. This approach may have resulted, however, in the inclusion of some occupations that are not causally related to risk. The slightly higher estimate was based on employment in either an a priori suspect occupation or in an occupation with an overall RR of at least 1.5 or a significant duration effect.

Our PAR estimates for occupation are consistent with those of two other case-control studies of bladder cancer (*13,28*). In studies in which the PAR for occupation was estimated directly, the following estimates were reported (listed in chronologic order):

Study area	Estimated PAR (%)	Reference
Leeds, United Kingdom	21	(*28*)
Massachusetts, USA	18	(*13*)
British Columbia, Newfoundland, and Nova Scotia, Canada	8	(*21*)
Turin, Italy	10	(*36*)
Mataro County, Spain	12	(*41*)
Charleroi and Liège, Belgium	54	(*25*)

In most of these studies, the definition of occupational risk used to compute the PAR was employment in an a priori suspect industry or occupation. The definition of a priori suspect industry or occupation, however, varied substantially from study to study.

Vineis and Simonato (*42*) attempted to remove these definitional differences by standardizing the definition of occupational risk and estimating the PAR for occupation based on data from nine bladder cancer case-control studies, which included data from two centers of our national study (*37,43*). Using three sets of criteria for defining occupational risk, they reported PAR estimates that ranged from 0% to 19%. Their results also indicated that for most studies, except those from the United States, variability in the PAR due to differences in the definition of occupational risk was negligible compared with "between-study variability." Our results indicate that similar estimates of the PAR for occupation are achieved among white men in the United States with either of two appropriate definitions of occupational risk.

The findings from this and other studies indicate that a dynamic relationship exists between occupation and bladder cancer risk. With the advent of new chemicals and the elimination of bladder carcinogens from the workplace, changed worker exposures are generating shifts in high-risk occupations. For example, excess risks among leather and rubber workers have diminished over time (*8,44*), and new high-risk occupations, such as truck driver and primary aluminum worker, have been identified (*7,45*). Occupational bladder cancer, which may be considered an index of occupational cancer hazards, continues to be a public health problem in many parts of the world, with risk changing over time and from population to population. Thus we need to exercise continued vigilance to identify new high-risk occupations, to determine which occupations are no longer associated with risk, and to quantify these changes.

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