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Occupational Exposure and the Risk of Barrett's Esophagus: A Case–Control Study

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Abstract

Background—Case–control studies in the United States and Europe have linked occupational exposure to volatile sulfur compounds, solvents, and pesticide to increased risk of esophageal adenocarcinoma. However, the association between occupational exposures and the risk of Barrett's esophagus (BE) is unclear given the absence of studies in this area.

Methods—This is a case–control study in patients undergoing endoscopy who were either referred directly or were eligible for screening colonoscopy and recruited from primary care clinics. All participants completed a survey on (1) self-reported occupational exposures to asbestos, metal dust, organic solvents, and pesticides, and (2) self reported longest held job and job-related activities. The latter were assigned by an industrial hygienist who was blinded to the case and control status into one of 99 standard occupational categories used by the US Department of Labor. Each occupational category was then assigned an expected level of exposure to the same four classes of agents in addition to radiation. We compared the self-reported exposure and the expected occupational exposure based on the self-reported occupation between cases with definitive BE and controls without BE. We examined the associations adjusting for age, sex, race, and patient recruitment source in a multivariable logistic regression analysis.

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Results—We examined 226 cases of definitive BE and 1,424 controls without BE. There was a greater proportion of patients with self-reported asbestos exposure in cases than controls (16.2 % vs. 12.0 %; $p = 0.08$) but no significant differences in metal dust, organic solvents, or pesticides. The multivariate model did not show an independent association between self-reported asbestos exposure and BE. For the calculated occupational exposure, there were no significant differences between cases and controls for asbestos (29.6 % vs. 27.5 %; $p = 0.5$), metal dust, organic solvents, pesticides, or radiation exposure. Among commonly reported occupation, there were significantly greater proportion of retail sales workers in BE cases than controls (10.8 % vs. 4.9 %; $p = 0.01$).

Conclusions—Exposure to asbestos and sedentary jobs may be risk factors for Barrett's esophagus. Further studies are needed to confirm this finding.

Keywords

Asbestos; Occupational epidemiology; Epidemiology; Risk factors

Introduction

Barrett's esophagus (BE) is an acquired disorder characterized by intestinal metaplasia of the normally stratified squamous epithelium of the esophagus. BE confers severalfold increase in the risk of adenocarcinoma of the esophagus [1]. In the Western world, esophageal adenocarcinoma has been rising over the past several recent decades [2]. Risk factors for BE and for the progression of BE to adenocarcinoma of the esophagus include gastroesophageal reflux disease (GERD), older age, male gender, and possibly abdominal obesity and tobacco smoking [2]. Given that BE follows a metaplasia to dysplasia to malignant transformation paradigm, it is possible that occupational risk factors, specifically exposure to carcinogens, would increase risk of BE or adenocarcinoma. Identifying these risk factors may lead to targeted screening and surveillance or other prevention efforts.

There are no published studies on occupational risk factors for BE. A few case-control studies performed in Europe and the United States [3–6] have suggested that exposure to volatile sulfur compounds, lead and solvents are associated with an increased risk of esophageal adenocarcinoma. Further, persons working in certain occupations including carpenters, animal product workers, electricians, and petroleum workers may have an increased risk of esophageal adenocarcinoma in one case-control study from Spain [3]. On the other hand, the association between exposure to pesticides and esophageal adenocarcinoma has been inconsistently reported [4–6]. The pathogenetic mechanisms, if any, underlying these associations are unknown. None of these studies examined BE, and therefore could not distinguish between risk factors for BE versus risk factors for progression of BE into cancer.

As part of a large cross-sectional study of risk factors for BE, we have analyzed self-reported occupational exposure (e.g., organic solvents and pesticides) as well as self reported occupations (e.g., manufacturing and construction) and their related activities. In this paper, we provide the first report on the distribution of the self reported occupational exposures as well as calculated exposures based on self reported occupations among patients with and without BE, and their possible associations with BE.

Methods

Study Population and Design

We selected cases and controls from two cross-sectional studies conducted at the Michael E. DeBakey VA Medical Center in Houston, TX. In the first cross sectional study, we recruited consecutive eligible patients who were scheduled for an elective esophagastroduodenoscopy

(EGD) starting in February 2008. In the second cross-sectional study, we recruited patients eligible for screening colonoscopy who were scheduled for a visit to one of seven selected primary care clinics between September 1, 2008 and December 31, 2010.

Recruitment and Eligibility Criteria

The electronic medical records of all veterans with a scheduled upper GI endoscopy were screened by trained research assistants to determine study eligibility based on the following criteria: (1) age between 40 and 80 years; (2) no previous gastro esophageal surgery; (3) no previous cancer of the esophagus; (4) no active lung, liver, colon, breast, or stomach cancer; (5) not taking anticoagulants; (6) no significant liver disease indicated by platelet count below 70,000, ascites or gastroesophageal varices; and (7) no history of major stroke or mental condition that would limit their ability to answer questions. For the primary care patients the same eligibility criteria were used with the exception of the age limit, which was raised to 50, the age when screening colonoscopies are recommended to commence.

This research was approved by the Institutional Review Boards for the Michael E. DeBakey VA Medical Center and Baylor College of Medicine.

Data Collection

All study participants completed a computer assisted survey administered by a research assistant before the endoscopy; answers were directly entered into Knightsoft (Farmington Hills, MI) and subsequently imported into SAS for analysis. All study participants underwent EGD with systematic recording of suspected BE according to the Prague CM classification and at least one targeted biopsy using Jumbo biopsy forceps. Definitive BE was considered in the presence of intestinalized columnar epithelia (confirmed by alcian-PAS stain) in the histopathological examination of biopsy samples obtained from suspected BE areas. Two expert pathologists reviewed all slides for suspected BE to determine the presence of definitive BE. Patients with no definitive or suspected BE served as controls in this analysis. Endoscopic-only BE was defined by the presence of suspected BE in the absence of specialized intestinal epithelium, and was excluded for this analysis.

Occupational History

The survey contained 12 questions on occupational exposure for more than 8 h per week for a period of 1 year or longer and the duration (if any) of exposure to the following compounds: asbestos, metal dust, organic solvents (paint thinner, ligroin, trichloroethylene, perchloroethylene, formaldehyde, benzene), and pesticides. In addition, there were questions regarding the job each subject held longest in their lifetime, including the industry in which the subject worked, main activities or duties of the job, and age at which the job was started and stopped (if applicable).

Quality Control

Internal validity logic checks were performed on the database. We reviewed 225 records from the biopsy confirmed BE group, 126 from the endoscopic suspected BE group, and 200 from our non-BE control group. Disagreement was observed in two biopsy confirmed BE cases (two of these were switched to endoscopic BE only), 13 endoscopic BE cases (all were changed to biopsy confirmed BE cases), and six non-BE controls (four reclassified to endoscopic BE, one to biopsy confirmed BE).

Exposure Assignment Based on Self-Reported Occupation

To assess the degree and type of exposures based on self-reported occupation, we created an occupation matrix for each participant using their longest held job and related job activities

using Occupational Information Network (O*NET), a standardized occupation coding classification available from the US Department of Labor which has been validated previously in the occupational literature [7–12]. The purpose of this coding was to quantify self-reported exposures across various occupations. The main advantage of incorporating a job exposure matrix in our study and in questionnaire-type studies in general is that it helps minimize the potential limitations of incomplete data which is inherent in questionnaire-type studies. The O*NET classification codes for 18 major occupations and the first subcategory for a total of 97 occupations. In order to assess whether exposure occurred to compounds of interest and what the degree of exposure was, a Certified Industrial Hygienist, co-investigator (LW), blinded to results of self-reported exposures and to the case/control status performed the coding.

We subsequently assigned the degree of estimated exposure for each occupational code across five different exposures: asbestos, metal dusts, organic solvents, pesticides, as well as radiation (see the Appendix). Degree of exposure in different occupational codes was cross-checked with existing literature [13, 14], and was assigned using a four point scale: 0 for none or very rare, 1 for infrequent or very low, 2 for any exposure higher than category 1, except that code 3 would be assigned for known, obvious, or high exposure. Certain highly exposed jobs for specific exposures were further coded based on job activities; for example, if the subject had reported being a welder (which would fall into the broader Construction Trades Worker occupation category), the metals exposure was raised.

Data Analysis

We compared definitive BE to controls without endoscopic or definitive BE. The main exposure variables were (1) self-reported occupational exposures to asbestos, metal dust, organic solvents, and pesticides, and (2) estimated exposure to asbestos, metal dust, organic solvents, and pesticides as well as radiation based on self-reported occupation. We also compared the distributions of the most commonly reported 20 occupations between cases and controls. We also compared the distribution of demographic characteristics (age, gender, race, education, income, and marital status) and other possible BE risk factors (BMI, waist hip ratio, tobacco smoking, alcohol drinking, GERD symptoms, *H pylori* infection and PPI treatment).

Chi-square and Fisher's exact tests were used for categorical variables and Wilcoxon's test for continuous variables. In multivariable logistic regression models, we adjusted for age, sex, race, patient recruitment source (endoscopy or primary care), BMI, waist hip ratio, tobacco smoking, alcohol drinking, GERD symptoms, *H pylori* infection and PPI treatment. The occupational risk factors were retained in the model in addition to other variables with *p* value <0.1. Parameter estimates and standard errors from the model were used to calculate odds ratios and their accompanying 95 % confidence intervals (CI).

Results

We analyzed 226 cases with definitive BE and 1,424 controls without definitive or endoscopic BE (Table 1). Most were men with a mean age of approximately 61 years. However, cases were an average of 1.2 years older than controls and more likely to be men of Caucasian race. There were no significant differences between cases and controls in the distribution of education status, household income or marital status.

There was a trend toward association between self-reported asbestos exposure and BE (16.2 % reported in cases vs. 12.0 % in controls, *p* = 0.08) but not with metal dust, organic solvents, or pesticides (Table 2). Multivariate analysis examining BE while adjusting for

age, gender, race and patient source, attenuated the association with self-reported asbestos exposure; the adjusted odds ratio was 1.11 (95 % CI 0.73–1.70, $p = 0.62$).

Table 3 shows the distribution of cases and controls with estimated degrees of exposure to asbestos, radiation, pesticides, solvents, or metals. These exposures were assigned to occupational categories that we constructed from self reported longest held job and its related activities. There were no statistically significant differences in unadjusted analyses, and similarly no significant associations in the multivariate analysis.

Among the top 20 most frequent occupations (see Table 4) constructed from the self reported longest held job and its related activities in the study population, only jobs in retail sales were significantly more prevalent among cases than controls (10.8 % vs. 4.9 %, relative proportion = 2.21, $p = 0.01$; Table 3). Controls tended to work more (relative proportions 0.5) in other protective services (0.31; $p = 0.07$), other installation/maintenance/repair (0.75), motor vehicle operators (0.77), and material recording, scheduling and dispatching (0.56).

Discussion

We conducted the first large single-center case–control study to evaluate the effect of occupational exposures on the risk of BE. Occupational exposure to asbestos, metal dust, solvents and pesticides was estimated using two methods: self reported exposures to these substances, and an estimated exposure based on self reported longest held occupation and its related activities. The main finding of our study was the possible association between self-reported asbestos exposure and increased risk of BE. This association was observed in unadjusted analyses only. However, we did not see an association with asbestos and BE when using the estimated exposure based on the occupation type. We also observed an association between sedentary jobs and increased BE risk.

Previous studies have shown that asbestos exposure is linked to a modestly increased risk of esophageal adenocarcinoma [3, 15]. A Spanish case–control study [3] comparing patients with newly diagnosed esophageal carcinoma with healthy matched controls showed an odds ratio of 3.46 with self-reported asbestos exposure (95 % CI 0.99–12.10) which did not reach statistical significance. Another nested case–control study in a cohort of Swedish construction workers [15] showed a statistically significant high incidence rate ratio of 4.5 (95 % CI 1.4–14.3) for esophageal adenocarcinoma, but not esophageal squamous cell carcinoma among those with asbestos exposure. The underlying pathogenetic mechanisms of any possible association between asbestos and BE or esophageal adenocarcinoma are unknown. Increased risk of mesothelioma and lung cancer has been well documented with asbestos primarily by an inhalational route, although asbestos fibers can also enter via oral ingestion [16, 17]. Asbestos fibers occur in two major morphologic forms: the long and pliable serpentine form (e.g., chrysotile) and short and stiff amphibole (e.g., tremolite and actinolite). Most (90–95 %) asbestos used in the United States is in the form of chrysotile, which is primarily used in occupations involving fabrics, whereas the amphibole form is primarily used in asbestos-cement pipes and floor tiles [16].

The findings must be interpreted in light of limitations. First, given the inherent limitations of a case–control study, causal inferences cannot be made. Second, this was a community not an industry based study. Therefore, well documented estimate levels of exposures characteristic of particular industries were lacking. On the other hand, community based studies have the advantage of examining multiple different exposures among subjects who worked in a wide array of different workplaces. In addition, we collected data on non occupational risk, which are typically missing in industry-based studies. Because

quantitative exposure data are not available, this study can only be regarded as providing valuable leads for more intensive investigation. Third, since exposures were based exclusively on self report without external validation, misclassification errors related to faulty recall were possible. However, all study subjects completed the occupational exposure before the study endoscopy, thus none of the study subjects or the investigators knew their case (BE) or control (no BE) status at the time of the occupational survey. Therefore, we are not aware of reasons for a differential misclassification that would explain, for example, the association between self reported exposure to asbestos and BE. Fourth, given that the definition for “occupation” included only longest held occupation, this may have limited the ability to measure the overall length of exposure and may have missed some exposures if participants held multiple jobs. However, the self reported exposure related to more than 8 h per week during a period of 1 year or longer. The wording of this question allows capture of exposure history (metal dust, organic solvents, pesticides, and asbestos) regardless of occupational changes over a subject’s lifetime.

The study population consists of veteran patients who are mostly low income men. Therefore, the generalizability of the findings to other groups is not known. Most self reported occupations were blue collar jobs such as construction workers, motor vehicle operators, and installation and maintenance occupation. Of the 99 possible occupational categories, 37 categories had at least ten participants from either case or control groups, and only four categories (construction workers, motor vehicle operators, installation and maintenance, and retail workers) had more than ten study participants in the BE case group. Although a statistically significant association was found between BE and the retail workers group, given the low number of participants in each group and the relatively tenuous association, we are unclear about the clinical or pathogenetic significance. Occupations with high exposure to radiation and pesticides were absent while the top occupations with asbestos exposure (firefighters, plumbers, plant and system operators) had more than ten participants in either case or control groups. Lastly, the discrepancy in the association between BE and asbestos based on self reported exposure (significant) and estimated exposures from self reported occupation (non significant) weakens but does not eliminate the argument of asbestos as a risk factor for BE.

The study is the first to assess occupational risk factors for BE, and therefore is novel. It employed a large sample size, and used thorough standardized definitions to determine the case and control status. The occupational survey was completed prospectively before the case or control status became known to the either study participants or interviewers and thus has limited the possibility of recall bias. We standardized the classification of occupations by having a certified industrial hygienist go through the answers to the occupational survey of 1,650 total patients and classify them according to standardized classification using the O*NET US Department of Labor classifications. Given that literature exists about different types of exposure per occupation, we created a semi quantitative estimate of exposure.

In summary, we found a possible association between asbestos self-reported exposure and sedentary jobs and increased risk of BE. Future studies need to confirm these associations.

Acknowledgments

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Appendix

See Table 5.

Table 1

Demographic characteristics of cases and controls

	Definitive BE (n = 226)	No BE (n = 1424)	p value
Age, mean (SD)	61.5 (7.0)	60.4 (8.0)	0.03
Men (%)	220 (97.3)	1304 (91.6)	0.002
Race (%)			0.0001
Caucasian	181 (80.1)	765 (53.7)	
African American	24 (10.6)	512 (36.0)	
Hispanic	19 (8.4)	120 (8.4)	
Other	2 (0.9)	27 (1.9)	
Education (%)			0.37
High school or less	103 (45.6)	633 (44.5)	
Some college	114 (50.4)	696 (48.9)	
College graduate	7 (3.1)	75 (5.2)	
NA	2 (0.9)	20 (1.4)	
Household income (%)			0.19
\$10,000 or less	33 (14.6)	275 (19.3)	
\$10,001–\$25,000	81 (35.8)	434 (30.5)	
\$25,001–\$50,000	67 (29.6)	393 (27.6)	
>\$50,000	40 (17.7)	283 (19.9)	
NA	5 (2.3)	39 (2.7)	
Marital status (%)			0.54
Married	133 (58.8)	782 (54.9)	
Divorced, separated, widowed	72 (31.9)	488 (34.2)	
Single never married	19 (8.4)	139 (9.8)	
NA	2 (0.9)	15 (1.1)	
Recruitment source (%)			<0.01
Scheduled for elective EGD	188 (83.2)	981 (68.9)	
Eligible for screening colonoscopy	38 (16.8)	443 (31.1)	
PPI use (%)			<0.001
No	63 (27.9)	679 (47.7)	
Yes	160 (70.8)	720 (50.6)	
NA	3 (1.3)	25 (1.7)	
GERD symptoms (%)			<0.001
None	79 (35.0)	770 (54.0)	
<10 years	37 (16.3)	232 (16.3)	
10+ years	108 (47.8)	407 (28.6)	
NA	2 (0.9)	15 (1.1)	
BMI (%)			0.46
<25	36 (15.9)	275 (19.3)	
25–30	84 (37.2)	522 (36.7)	
>30	106 (46.9)	627 (44.0)	

	Definitive BE (<i>n</i> = 226)	No BE (<i>n</i> = 1424)	<i>p</i> value
WHR (%)			<0.001
Low	16 (7.1)	230 (16.2)	
High ^a	208 (92.0)	1152 (80.9)	
NA	2 (0.9)	42 (2.9)	
<i>H. pylori</i> (%)			<0.001
Negative	180 (79.6)	942 (66.2)	
Positive	40 (17.7)	410 (28.8)	
NA	6 (2.7)	72 (5.0)	
Smoking (%)			0.07
Non-smoker	49 (22.4)	415 (29.7)	
<30 Pack-years	78 (35.6)	467 (33.5)	
30 Pack-years	92 (42.0)	513 (36.8)	
Alcohol use (%)			0.66
Never drank	17 (7.6)	131 (9.4)	
Former drinker	87 (39.0)	550 (39.4)	
Current drinker	119 (53.4)	716 (51.2)	

BE Barrett's esophagus, SD standard deviation, NA not available, EGD esophagastroduodenoscopy, PPI proton pump inhibitor, GERD gastroesophageal reflux disease, BMI body mass index, WHR waist-hip ratio

^a >0.9 for men, >0.85 for women

Table 2

Comparison of self-reported occupational exposure between cases with definitive BE and controls without definitive or endoscopic BE. The comparisons are made in unadjusted and adjusted analyses (Patients who did not know their occupational exposure to a particular agent (DK) were omitted from that analysis)

Self-reported exposure	Definitive BE (n = 226)	No BE (n = 1424)	Unadjusted odds ratio (95 % CI)	Adjusted odds ratio (95 % CI) ^a	p value unadjusted; adjusted
Asbestos					0.08; 0.62
Yes	36 (15.9)	169 (11.9)	1.41 (0.96–2.09)	1.11 (0.73–1.70)	
No	186 (82.3)	1235 (86.7)	Ref		
DK	4 (1.8)	20 (1.4)			
Metal dust					0.74; 0.22
Yes	36 (15.9)	215 (15.1)	1.07 (0.73–1.59)	0.77 (0.51–1.17)	
No	188 (83.2)	1198 (84.1)	Ref		
DK	2 (0.9)	11 (0.8)			
Organic solvents					0.62; 0.13
Yes	32 (14.2)	184 (12.9)	1.11 (0.74–1.66)	0.71 (0.46–1.10)	
No	193 (85.4)	1229 (86.3)	Ref		
DK	1 (0.4)	11 (0.8)			
Pesticides					0.20; 0.93
Yes	14 (6.2)	61 (4.3)	1.49 (0.82–2.70)	0.97 (0.50–1.90)	
No	209 (92.5)	1353 (95.0)	Ref		
DK	3 (1.3)	10 (0.7)			

^a Adjusted for age, sex, race, patient recruitment source, PPI, GERD, BMI, WHR, *H. pylori*, smoking status, and drinking status

BE Barrett's esophagus, CI confidence interval, Ref reference, PPI proton pump inhibitor, GERD gastroesophageal reflux disease, BMI body mass index, WHR waist-hip ratio

Table 3
Comparison of estimated exposures based on self reported occupations. Results from adjusted comparisons

Exposure	Degree of exposure	BE definitive (n = 226)	Controls (n = 1424)	Adjusted OR ^a	p value
Asbestos	0	159 (70.4)	1032 (72.5)	Ref	
	1	1 (0.4)	4 (0.3)	1.51 (0.14–15.99)	0.73
	2	61 (27.0)	365 (25.6)	0.96 (0.68–1.36)	0.83
	3	5 (2.2)	23 (1.6)	1.34 (0.48–3.73)	0.58
Metals	1, 2, or 3	67 (29.6)	392 (27.5)	0.99 (0.71–1.38)	0.96
	0	156 (69.0)	1065 (74.8)	Ref	
	1	29 (12.8)	128 (9.0)	1.35 (0.83–2.18)	0.23
	2	36 (15.9)	205 (14.4)	1.12 (0.74–1.69)	0.61
Organic solvents	3	5 (2.3)	26 (1.8)	1.27 (0.46–3.50)	0.65
	1, 2, or 3	70 (31.0)	359 (25.2)	1.21 (0.87–1.68)	0.27
	0	125 (55.3)	826 (58.0)	Ref	
	1	28 (12.4)	242 (17.0)	0.76 (0.48–1.21)	0.25
Pesticides	2	70 (31.0)	348 (24.4)	1.23 (0.87–1.73)	0.24
	3	3 (1.3)	8 (0.6)	2.46 (0.57–10.64)	0.23
	1, 2, or 3	101 (44.7)	598 (42.0)	1.07 (0.79–1.44)	0.68
	0	210 (92.9)	1302 (91.4)	Ref	
Radiation	1	13 (5.8)	90 (6.3)	1.08 (0.57–2.05)	0.82
	2	3 (1.3)	32 (2.3)	1.16 (0.33–4.03)	0.81
	1 or 2	16 (7.1)	122 (8.6)	1.09 (0.61–1.95)	0.76
	0	213 (94.2)	1357 (95.3)	Ref	
	1	13 (5.8)	65 (4.6)	1.20 (0.61–2.37)	0.59
	2	0 (0.0)	2 (0.1)		
	1 or 2	13 (5.8)	67 (4.7)	1.19 (0.61–2.34)	0.61

^a Adjusted for age, sex, race, patient recruitment source, PPI, GERD, BMI, WHR, *H pylori*, smoking status, and drinking status

BE Barrett's esophagus, OR odds ratio, Ref reference, PPI proton pump inhibitor, GERD gastroesophageal reflux disease, BMI body mass index, WHR waist-hip ratio

Table 4

A comparison of the distribution of the 20 most commonly reported occupations among cases and controls. The classification was performed using the Occupational Information Network (O*NET) on self reported longest held job and related job activities

O*NET occupation	Barrett's esophagus (BE) N = 158	Control N = 1025	% of cases/% of controls	p value
47–2000 Construction trade workers	41 (25.9)	231 (22.5)	1.15	0.50
53–3000 Motor vehicle operators	15 (9.5)	127 (12.4)	0.77	0.31
49–9000 Other installation, maintenance, and repair occupations	11 (7.0)	95 (9.3)	0.75	0.38
43–5000 Material recording, scheduling, dispatching, and distribution workers	7 (4.4)	81 (7.9)	0.56	0.11
55–3000 Military enlisted tactical operations and air/weapons specialists	11 (7.0)	70 (6.8)	1.02	0.98
41–2000 Retail sales workers	17 (10.8)	50 (4.9)	2.21	0.01
33–9000 Other protective services workers	2 (1.3)	42 (4.1)	0.31	0.07
51–4000 Metal workers and plastic workers	5 (3.2)	34 (3.3)	0.95	0.87
11–3000 Operations specialties managers	7 (4.4)	30 (2.9)	1.51	0.33
51–8000 Plant and system operators	6 (3.8)	31 (3.0)	1.26	0.63
15–1100 Computer occupations	4 (2.5)	31 (3.0)	0.84	0.69
49–3000 Vehicle and mobile equipment mechanics, installers, and repairers	7 (4.4)	24 (2.3)	1.89	0.18
41–1000 Supervisors of sales workers	4 (2.5)	25 (2.4)	1.04	0.99
47–1000 Supervisors of construction and extraction workers	4 (2.5)	23 (2.2)	1.13	0.78
29–1000 Health diagnosing and treating practitioners	2 (1.3)	24 (2.3)	0.54	0.57
11–2000 Advertising, marketing, promotions, public relations, and sales managers	2 (1.3)	24 (2.3)	0.54	0.57
13–1000 Business operations specialists	5 (3.2)	20 (2.0)	1.62	0.37
13–2000 Financial specialists	3 (1.9)	22 (2.1)	0.88	0.80
41–3000 Sales representatives, services	2 (1.3)	22 (2.1)	0.59	0.76
49–2000 Electrical and electronic equipment mechanics, installers, repairers	3 (1.9)	19 (1.9)	1.02	0.99

Table 5

Estimated exposure assessment of different occupations

General categories	
0 = None or very rare and very low	
1 = Infrequent and very low, but possible	
2 = Anything more frequent or higher than cat. 1, except known, obvious high	
3 = Known, obvious, high (approaches or exceeds occupational exposure standards on at least some days)	
Exposure level	O*NET occupation
Radiation	
3	Industrial radiographers
3	Navy nuclear sub crews
2	19–4000 Life, physical, and social science technicians
2	29–2000 Health technologists and technicians
2	31–9000 Other healthcare support occupations
2	51–8011 Nuclear power reactor operators
1	25–1000 Postsecondary teachers
1	29–1000 Health diagnosing and treating practitioners
1	53–2000 Air transportation workers
Asbestos	
3	33–2000 Fire fighting and prevention workers
3	Boiler makers, insulators, plumbers based on job titles
3	Ship engine room operators
3	Shipbuilders based on job title
2	47–2000 Construction trades workers
2	47–4000 Other construction and related workers
2	49–3000 Vehicle and mobile equipment mechanics, installers, and repairers
2	49–9000 Other installation, maintenance, and repair occupations
2	51–8000 Plant and system operators
1	47–3000 Helpers, construction trades
Metals	
3	All welders based on job title reported
2	47–2000 Construction trades workers
1	19–2000 Physical scientists
1	19–4000 Life, physical, and social science technicians
1	33–2000 Fire fighting and prevention workers
1	37–3000 Grounds maintenance workers
1	45–2000 Agricultural workers
1	47–3000 Helpers, construction trades
1	47–5000 Extraction workers
1	49–2000 Electrical and electronic equipment mechanics, installers, and repairers
1	49–3000 Vehicle and mobile equipment mechanics, installers, and repairers
1	51–2000 Assemblers and fabricators

Exposure level	O*NET occupation
1	51–4000 Metal workers and plastic workers
Organics	
3	51–2000 Assemblers and fabricators
3	51–5100 Printing workers
2	39–5000 Personal appearance workers
2	47–2000 Construction trades workers
2	47–5000 Extraction workers
2	49–3000 Vehicle and mobile equipment mechanics, installers, and repairers
2	51–4000 Metal workers and plastic workers
2	51–7000 Woodworkers
2	51–8000 Plant and system operators
2	53–4000 Rail transportation workers
2	53–5000 Water transportation workers
1	19–1000 Life scientists
1	27–1000 Art and design workers
1	29–1000 Health diagnosing and treating practitioners
1	29–2000 Health Technologists and Technicians
1	37–2000 Building cleaning and pest control workers
1	37–3000 Grounds maintenance workers
1	39–4000 Funeral service workers
1	45–4000 Forest, conservation, and logging workers
1	47–3000 Helpers, construction trades
1	49–2000 Electrical and electronic equipment mechanics, installers, and repairers
1	51–6000 Textile, apparel, and furnishings workers
1	53–2000 Air transportation workers
1	53–3000 Motor vehicle operators
1	53–6000 Other transportation workers
1	53–7000 Material moving workers
1	99–9998 Housewife
Pesticides	
2	37–2000 Building cleaning and pest control workers
2	37–3000 Grounds maintenance workers
2	45–2000 Agricultural workers
1	35–9000 Other food preparation and serving related workers
1	37–1000 Supervisors of building and grounds cleaning and maintenance workers
1	39–2000 Animal care and service workers
1	45–1000 Supervisors of farming, fishing, and forestry workers
1	45–4000 Forest, conservation, and logging workers
1	51–3000 Food processing workers
1	53–5000 Water transportation workers
1	55–1000 Military officer special and tactical operations leaders
1	55–2000 First-line enlisted military supervisors
1	55–3000 Military enlisted tactical operations and air/weapons specialists and crew members