Cancer Mortality in Female and Male Dry-Cleaning Workers

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A cohort study of dry-cleaning workers (1109 women, 592 men) in the mid-1980s revealed significant excess bladder cancer mortality. This article updates vital status through 1990. Significant excesses were seen for bladder cancer (nine deaths, standardized mortality ratio [SMR] = 2.54, 95% confidence interval [CI] = 1.16–4.82), esophageal cancer (10 deaths, SMR = 2.14, 95% CI = 1.02–3.94), and intestinal cancer (26 deaths, SMR = 1.56, 95% CI = 1.02–2.29). In a subcohort exposed only to perchloroethylene (PCE), those with 5 or more years of employment and 20 or more years since first exposure had a significant increased risk of esophageal cancer (four deaths, SMR = 7.17, 95% CI = 1.92–19.82). Women had significant excess esophageal cancer (five deaths, SMR = 3.24, 95% CI = 1.05–7.58) and elevated SMRs for intestinal, pancreatic, and bladder cancer mortality. This study confirms the esophageal cancer risk among dry-cleaning workers seen in another study and suggests an association with PCE. It further documents the risks for intestinal, pancreatic, and bladder cancers in this industry.

Dry-cleaning workers experience prolonged exposure to solvents. Historically, these have included carbon tetrachloride, petroleum solvents (Stoddard solvent), trichloroethylene, and tetrachloroethylene (perchloroethylene [PCE]). PCE is now used by over 90% of dry-cleaning plants[1] as a cleaning fluid and by other industries as a degreaser[2] and solvent.[3] The National Occupational Exposure Survey (NOES) estimated (November 27, 1989) that over 500,000 dry-cleaning and other industrial workers potentially are exposed to PCE. Stoddard solvent, a petroleum-based mixture of alkane and aromatic hydrocarbons, is used by about 10% of dry-cleaning plants and by a wide variety of other industries as a degreaser, metal cleaner, and paint remover. About 1.7 million workers potentially are exposed to Stoddard solvent, according to NOES.

Dry cleaning is waterless machine laundering. Textiles are immersed in a nonaqueous solvent and detergent, agitated, spun to extract excess solvent, and tumble dried in warm air, in the same machine or in a separate dryer. Stains are spot cleaned before or after laundering. Ludwig et al[1] found that in plants with separate washers and dryers, machine operators who hand-transferred solvent-permeated clothes were exposed to an average of 23 ppm (156 mg/m^3) PCE; however, in plants with combination equipment, average operator exposure was 16 ppm (108 mg/m^3) PCE. Pressers, seamstresses, and counter personnel had much lower exposure.[1] Occupational exposure to PCE and Stoddard solvent is regulated by Occupational Safety and Health Administration (OSHA) standards: an 8-hour time-weighted average (TWA) of no more than 100 ppm (678 mg/m^3)

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PCE and a peak exposure of no more than 200 ppm (1,356 mg/m^3) for 5 minutes every 3 hours. The National Institute for Occupational Safety and Health (NIOSH) currently recommends that PCE be treated as if it were carcinogenic (i.e., no safe exposure levels).[4] OSHA mandates an 8-hour TWA to Stoddard solvent of no more than 100 ppm (525 mg/m^3), although NIOSH recommends a TWA of no more than 67 ppm (350 mg/m^3).[4]

Perchloroethylene is a known animal carcinogen,[5] but there is inadequate evidence of human carcinogenicity (International Agency for Research on Cancer [IARC] Group 2B).[6] National Cancer Institute (NCI) bioassays have been evaluated as providing clear evidence of mouse carcinogenesis by gavage and mouse and rat carcinogenesis by inhalation. The NCI bioassay indicated that PCE induced liver tumors in exposed mice,[7] and a National Toxicology Program study revealed that PCE produced increased incidence of renal adenomas or adenocarcinomas in male rats, increased incidence of leukemia in rats, and a dose-related increase in hepatocellular tumors in mice.[5]

Stoddard solvent pharmacologically and toxicologically resembles gasoline.[8] Mouse dermal assays have revealed weakly carcinogenic activity for mixtures that contain many of the same compounds as those found in Stoddard solvent and chronic inhalation of unleaded gasoline—similar in composition to Stoddard solvent—produced renal tumors in male rats and hepatocellular tumors in female mice.[9]

The original NIOSH study (of which this is an update) investigated mortality among 1,708 dry-cleaning workers (65% women, 52% nonwhite) with PCE and other solvent exposures, including 615 workers who were exposed only to PCE.[2] Although overall mortality was less than expected, cancer mortality was increased (142 deaths, SMR = 1.16, 95% CI = 0.97–1.36). The increase was significant for bladder cancer (8 deaths, SMR = 2.96, 95% CI = 1.28–5.86) and for urinary organs (bladder and kidney) overall (12 deaths, SMR = 2.55, 95% CI = 1.32–4.50).

Our primary objective was to investigate the increased risk of bladder cancer observed in the first study by Brown and Kaplan.[2] The animal literature suggested that PCE can act as a carcinogen at multiple sites. Therefore, a secondary objective was to investigate whether this cohort also has increased risk of other cancers, especially those of the liver, kidney, and lung.

Methods

The Brown and Kaplan[2] cohort was assembled from dry-cleaning union records in four cities (in California, Illinois, Michigan, and New York). Employees who had worked for at least 1 year before 1960 at a shop using PCE as the primary solvent and who were not known to have been exposed to carbon tetrachloride were eligible for the study. For cohort members, their periods of work at non-PCE shops were included in work histories, but the specific solvent used was not coded. The study determined vital status as of December 31, 1982. After checking union records and plant solvent histories, Brown and Kaplan[2] defined a subcohort of workers who had been employed only in shops in which PCE was the primary solvent (PCE-only subcohort). Exposure in those shops in which solvent usage could not be determined was coded as "other solvent," which could be PCE or another solvent, mostly petroleum solvents. Those who worked in both PCE and other solvent shops comprised the "PCE-plus" subcohort.

We used the National Death Index to ascertain mortality through December 31, 1990. Analytic methods were those used in the original investigation.[2] SMRs were derived using the modified life-table analysis system developed by NIOSH[10,11] to calculate person-years at risk (PYAR) and the expected number of deaths. Each person contributes 1 PYAR for each year that he/she was alive during the period of observation. For our study, the period of observation started January 1, 1940 or after 1 year of employment in a PCE plant, whichever was later, and ended at the date of death or December 31, 1990, whichever was earlier.

Gender and race-specific PYAR were stratified into 5-year intervals by age and calendar time and then multiplied by the appropriate cancer mortality rate to calculate the expected number of deaths for that stratum. The expected numbers of deaths in all strata were summed to yield the total expected number. The SMR is the ratio of observed to expected numbers of deaths. Its statistical significance was tested with the simple continuity corrected χ^2 statistic. This ratio is derived with the assumption that the observed number of deaths approximately follows a Poisson distribution, with mean and variance both equal to the expected number.[12,13] This SMR probably underestimated the true risk, because (*a*) we may have missed deaths and (*b*) we allowed PYAR to accumulate to the end of the study. We also calculated SMRs separately for the two subcohorts, PCE-only and PCE-plus. We calculated SMR by duration of employment in dry-cleaning shops using PCE (1 to 5 years, 5+ years) as a surrogate for PCE exposure and by latency periods (less than 20 years, 20+ years). Our tables present the number of deaths observed, the SMR, and the 95% CI (two-sided) for the SMR.

Results

The current composition and status of the cohort and the subcohorts with PCE-only and PCE-plus exposures are shown in Table 1. It should be noted that both subcohorts had approximately 6 years of employment in known PCE shops. The PCE-plus subcohort also had a mean of approximately 5 years of employment in shops using other solvents (PCE and/or petroleum solvents).

Deaths overall from causes other than cancer were not elevated. Cancer deaths overall were in excess (Table 2). There were 209 cancer deaths observed and 169.7 expected, for an SMR of 1.23 (95% CI = 1.07–1.41). Cancer mortality was significantly el-

TABLE 1
Composition of Entire Cohort and Subcohorts (as of December 31, 1990)

Characteristic	Entire Cohort (n = 1,708)	PCE Only (n = 625)	PCE Plus (n = 1,083)
Excluded from analysis*	7 (0.7%)	4 (0.8%)	3 (0.3%)
Racial distribution			
Women	1109 (65%)	414 (67%)	695 (64%)
White	522 (47%)	191 (46%)	331 (48%)
Nonwhite	587 (53%)	223 (54%)	364 (52%)
Men	592 (35%)	207 (33%)	385 (36%)
White	299 (51%)	108 (52%)	191 (50%)
Nonwhite	293 (49%)	99 (48%)	194 (50%)
Vital status			
Women			
Alive	624 (56%)	272 (66%)	352 (51%)
Dead	415 (37%)	116 (28%)	299 (43%)
Unknown†	70 (6%)	26 (6%)	44 (6%)
Men			
Alive	216 (36%)	92 (44%)	124 (32%)
Dead	354 (60%)	106 (51%)	248 (64%)
Unknown†	22 (4%)	9 (4%)	13 (3%)
Mean year of birth	1916 ± 11.6	1919 ± 11.9	1914 ± 11.0
Mean year first employed	1951 ± 5.7	1953 ± 4.6	1949 ± 5.7
Mean age at first employment	34.6 ± 10.2	34.2 ± 10.8	34.8 ± 9.8
Mean duration of employment‡	9.6 ± 6.8	6.4 ± 5.5	11.4 ± 6.7
Using PCE		6.4 ± 5.5	6.0 ± 4.7
Using other solvents		—	5.3 ± 5.0
Mean year of death	1977 ± 9.1	1978 ± 9.2	1977 ± 9.1
Person-years at risk from PCE exposure	47,273	17,939	29,334
Latency <20 years	29,408	10,884	17,598
Latency ≥20 years	17,865	7,055	11,736
1–5 years exposure	28,412	10,810	18,517
≥5 years exposure	18,861	7,129	10,817

* Missing information (eg, date of birth) essential for the analysis.
† Workers whose vital status was unknown as of December 31, 1979, when the National Death Index system was initiated and for whom additional information has not been received.
‡ Through 1982.

evated among workers with 20 or more years of latency since first exposure and 5 or more years of employment in PCE shops (83 deaths, SMR = 1.50, 95% CI = 1.20–1.87) (Table 3). A similar pattern of increased mortality with longer latency and employment was seen for the three cancers in significant excess—esophageal, intestinal, and bladder—and for pancreatic cancer (Table 3). In analyses repeated using duration of employment in *any* dry-cleaning shop, results (not shown) were similar. Elevated SMRs for esophageal, intestinal, and bladder cancers also were seen across geographic locations, whether US or local rates were used (results not shown). The increases continue the trends seen in the first cohort report,[2] especially for bladder, intestinal, and pancreatic cancers (Table 3).

Women (Table 2) experienced a statistically significant excess of esophageal cancer (SMR = 3.24, 95% CI = 1.07–7.58) deaths and elevated SMRs for intestinal, pancreatic, and urinary tract cancers. Deaths from breast cancer (SMR = 1.08, 95% CI = 0.65–1.69) and from cancers of the female genital organs (SMR = 1.30, 95% CI = 0.80–2.01) were not in excess among women. Elevated SMRs for esophageal, intestinal, and pancreatic cancers were seen in men (Table 2), with significant excess mortality for tongue cancer (SMR = 5.48, 95% CI = 1.13–16.02) and bladder cancer (SMR = 3.27, 95% CI = 1.31–6.74).

In the older, larger subcohort exposed to both PCE and other solvents, intestinal, pancreatic, and bladder cancers were in significant excess (Table 4). Mortality due to esophageal cancer was elevated in both the PCE-only and PCE-plus subcohorts (Table 4). Among PCE-only workers with 5 or more years of employment and 20 or more years of latency, esophageal cancer deaths were in significant excess (4 deaths, SMR = 7.17, 95% CI = 1.92–19.82).

Discussion

Previous studies have reported elevated rates for urinary tract,[8,14,15] esophageal,[14] and pancreatic[16,17] cancers in dry-cleaning workers. In nearly all of these studies it could not be determined which specific solvent(s) each worker was exposed to. In a number of these studies, grouping laundry workers, who have no occupational exposure to solvents, with dry-cleaning workers, who are exposed to solvents, could have masked or diluted the effects of solvent exposure on risk of cancer.

Among over 5,300 dry-cleaning union members with mixed solvent exposures, Blair et al[14] found significant excess esophageal and cervical cancer mortality and excess deaths from bladder, thyroid, lung, and laryngeal cancers and lymphomas. In an earlier study, Blair and coworkers[18] found significantly elevated proportionate mortality ratios (PMRs) for total cancer (128) and lung (170), cervical (208), and skin (429) cancers in members of a laundry and dry-cleaning workers' union.

In a case-control study of incident bladder cancer, Schoenberg and coworkers[19] reported an odds ratio of 1.33 (not statistically significant) for dry-cleaning workers. Lin and Kessler[17] found that significantly more (33% vs 15%) of pancreatic cancer cases than controls worked in dry

TABLE 2
Cancer Mortality for Dry-cleaning Workers (through December 30, 1990)

Cause of Death	International Classification of Diseases Codes (9th Rev)	Entire Cohort (n = 1,701)			Women (n = 1,109)			Men (n = 592)		
		Deaths	Standardized Mortality Ratio	95% Confidence Interval	Deaths	Standardized Mortality Ratio	95% Confidence Interval	Deaths	Standardized Mortality Ratio	95% Confidence Interval
Buccal and pharynx	140–149	6	1.64	0.60–3.56	1	0.77	0.02–4.25	5	2.12	0.69–4.95
Tongue	141	3	3.54	0.73–10.4	0	0.00		3	5.48*	1.13–16.0
Digestive organs	150–159	63	1.31*	1.01–1.68	37	1.48*	1.04–2.04	26	1.13	0.74–1.66
Esophagus	150	10	2.14*	1.02–3.94	5	3.24*	1.05–7.58	5	1.60	0.52–3.73
Stomach	151	5	0.61	0.20–1.43	3	0.86	0.18–2.53	2	0.43	0.05–1.54
Intestine (except rectum)	152–153	26	1.56*	1.02–2.29	17	1.69	0.98–2.70	9	1.37	0.63–2.61
Rectum	154	5	1.27	0.41–2.97	3	1.47	0.30–4.30	2	1.05	0.13–3.80
Liver and biliary	155, 156	1	0.21	0.00–1.70	0			1	0.45	0.01–3.64
Pancreas	157	15	1.66	0.93–2.75	8	1.63	0.70–3.22	7	1.70	0.68–3.51
Peritoneum and unspecified digestive organs	158, 159	1	1.18	0.03–6.54	1	2.01	0.05–11.2	0	0.00	
Respiratory system	160–165	46	1.19	0.87–1.59	13	1.04	0.56–1.79	33	1.26	0.87–1.77
Larynx	161	2	1.29	0.16–4.67	1	2.94	0.07–16.3	1	0.83	0.02–4.61
Trachea, bronchus, and lung	162	43	1.18	0.85–1.59	12	1.01	0.52–1.76	31	1.26	0.85–1.79
Nasal and other parts	160, 163–165	1	1.97	0.05–10.9	0	0.00		1	3.41	0.08–19.0
Breast	174–175	19	1.08	0.65–1.68	19	1.08	0.65–1.69	0	0.00	
Female genital organs	179–184	20	1.30	0.80–2.01	20	1.30	0.80–2.01	—		
Cervix uteri	180	10	1.80	0.86–3.31	10	1.80	0.86–3.31	—		
Other and unspecified parts of uterus	179	5	1.28	0.41–3.00	5	1.28	0.41–3.00	—		
Ovary, Fallopian tube, and broad ligament	183	5	0.93	0.30–2.16	5	0.93	0.30–2.16	—		
Other female genital organs	184	0	0.00		0	0.00		—		
Male genital organs	185–187	8	0.91	0.39–1.80	—			8	0.91	0.39–1.80
Prostate	185	7	0.82	0.33–1.69	—			7	0.82	0.33–1.69
Urinary organs	188–189	13	2.07*	1.10–3.54	5	1.88	0.61–4.40	8	2.21	0.95–4.35
Kidney	189.0–189.2	4	1.46	0.40–3.74	3	2.41	0.50–7.03	1	0.67	0.02–3.73
Bladder and other urinary organs	188,189.3–189.9	9	2.54*	1.16–4.82	2	1.42	0.17–5.13	7	3.27*	1.31–6.74
Lymphatic and hematopoietic	200–208	9	0.69	0.32–1.31	4	0.56	0.15–1.44	5	0.85	0.27–1.98
Lymphosarcoma and reticulosarcoma	200	2	0.99	0.12–3.58	0	0.00		2	2.12	0.26–7.65

TABLE 2—Continued
Cancer Mortality for Dry-cleaning Workers (through December 30, 1990)

Cause of Death	International Classification of Diseases Codes (9th Rev)	Entire Cohort (n = 1,701)			Women (n = 1,109)			Men (n = 592)		
		Deaths	Standardized Mortality Ratio	95% Confidence Interval	Deaths	Standardized Mortality Ratio	95% Confidence Interval	Deaths	Standardized Mortality Ratio	95% Confidence Interval
Hodgkin's disease	201	0	0.00		0	0.00		0	0.00	
Leukemia and aleukemia	204–208	2	0.40	0.05–1.44	2	0.76	0.09–2.74	0	0.00	
Other lymphatic/ hematopoietic	202, 203	5	0.97	0.32–2.28	2	0.67	0.08–2.42	3	1.40	0.29–4.08
Other sites	170–173 190–199	25	1.37	0.88–2.02	13	1.25	0.67–2.15	12	1.51	0.78–2.65
Neoplasms of benign and unspecified nature	210–239	0	0.00		0	0.00		0	0.00	
All cancers	140–208	209	1.23†	1.07–1.41	112	1.22*	1.00–1.47	97	1.25*	1.01–1.52
Total deaths		769	1.01	0.94–1.09	415	1.06	0.96–1.17	354	0.96	0.86–1.06

* 95% confidence interval excludes the null value (1.0).
† 99% confidence interval excludes the null value.

TABLE 3
Standardized Mortality Ratios* for Selected Cancers in the Total Dry-cleaning Cohort, by Latency and Duration of Employment in Perchloroethylene Shops, Comparing Current and Earlier† Results

Site	Latency <20 years Duration <5 years	Latency <20 years Duration 5+ years	Latency 20+ years Duration <5 years	Latency 20+ years Duration 5+ years	Total Deaths Through 1990	Total Deaths Through 1982
All	24 deaths 0.65 (0.4–0.98)‡	32 deaths 1.19 (0.8–1.7)	70 deaths 1.38 (1.1–1.8)‡	83 deaths 1.50 (1.2–1.9)§	209 deaths 1.23 (1.1–1.4)§	142 deaths 1.16 (0.97–1.4)
Esophagus	0 deaths 0.00	0 deaths 0.00	2 deaths 1.42 (0.2–6.2)	8 deaths 5.40 (2.3–11.0)§	10 deaths 2.14 (1.0–3.9)§	4 deaths 1.17 (0.3–3.0)
Intestine	2 deaths 0.62 (0.1–2.7)	4 deaths 1.68 (0.5–4.7)	9 deaths 1.74 (0.8–3.4)	11 deaths 1.87 (0.9–3.4)	26 deaths 1.56 (1.0–2.3)§	16 deaths 1.36 (0.8–2.2)
Pancreas	1 death 0.57 (0.0–4.7)	2 deaths 1.50 (0.2–6.5)	5 deaths 1.81 (0.7–4.5)	7 deaths 2.22 (0.9–4.8)	15 deaths 1.66 (0.9–2.8)	11 deaths 1.72 (0.9–3.1)
Lung	4 deaths 0.65 (0.2–1.8)	6 deaths 1.28 (0.5–2.9)	21 deaths 1.67 (1.0–2.6)‡	12 deaths 0.91 (0.5–1.6)	43 deaths 1.18 (0.9–1.6)	27 deaths 1.13 (0.7–1.6)
Breast	3 deaths 0.67 (0.1–2.2)	3 deaths 0.90 (0.2–2.9)	6 deaths 1.21 (0.4–2.8)	7 deaths 1.45 (0.6–3.1)	19 deaths 1.08 (0.7–1.7)	12 deaths 0.87 (0.5–1.5)
Cervix	2 deaths 0.93 (0.1–4.1)	4 deaths 2.71 (0.7–7.5)	2 deaths 2.12 (0.2–9.2)	2 deaths 2.03 (0.2–8.8)	10 deaths 1.80 (0.9–3.3)	10 deaths 1.96 (0.95–3.6)
Kidney	2 deaths 3.39 (0.4–14.7)	1 death 2.33 (0.0–19.0)	0 deaths 0.00	1 death 1.12 (0.0–9.2)	4 deaths 1.46 (0.4–3.7)	4 deaths 2.00 (0.6–5.2)
Bladder	0 deaths 0.00	0 deaths 0.00	1 death 0.97 (0.0–7.9)	8 deaths 6.50 (2.8–13.2)§	9 deaths 2.54 (1.2–4.8)§	8 deaths 2.96 (1.3–5.9)§

* 95% confidence interval given in parentheses.
† Source: Brown DP, Kaplan SD. Retrospective cohort mortality study of dry cleaner workers using perchloroethylene. *J Occup Med.* 1987;29:535–541.
‡ 95% confidence interval excludes the null value (1.0).
§ 99% confidence interval excludes the null value.

TABLE 4
Cancer Mortality in the Perchloroethylene (PCE)-only and PCE-plus Subcohorts,* for Selected Sites

Cancer Site	PCE-only			PCE-plus		
	Number	Standardized Mortality Ratio	95% Confidence Interval	Number	Standardized Mortality Ratio	95% Confidence Interval
Buccal cavity and pharnyx	3	2.51	0.52–7.33	3	1.22	0.25–3.56
Tongue	2	7.25	0.88–26.2	1	1.75	0.04–9.74
Digestive organs	11	0.75	0.38–1.35	52	1.56‡	1.16–2.04
Esophagus	4	2.64	0.72–6.76	6	1.90	0.69–4.14
Stomach	0	0.00		5	0.87	0.28–2.04
Intestine, except rectum	5	1.00	0.32–2.33	21	1.81†	1.12–2.76
Rectum	0	0.00		5	1.81	0.58–4.22
Pancreas	2	0.73	0.09–2.62	13	2.08†	1.11–3.55
Respiratory system	14	1.12	0.61–1.88	32	1.23	0.84–1.73
Breast	6	1.00	0.36–2.17	13	1.12	0.59–1.91
Female genital organs	8	1.57	0.68–3.10	12	1.17	0.60–2.04
Male genital organs	2	0.89	0.11–3.21	6	0.92	0.34–2.00
Urinary organs	1	0.54	0.01–3.00	12	2.71‡	1.40–4.73
Kidney	1	1.16	0.03–6.45	3	1.60	0.33–4.68
Bladder and other urinary organs	0	0.00		9	3.52‡	1.61–6.68
Lymphatic and hematopoietic	2	0.49	0.06–1.77	7	0.78	0.31–1.61
Other sites	7	1.19	0.48–2.45	18	1.45	0.86–2.29
Neoplasms of benign and unspecified nature	0	0.00		0	0.00	
All cancers	54	1.01	0.76–1.32	155	1.33‡	1.13–1.56
Total deaths	222	0.97	0.84–1.10	547	1.03	0.95–1.12

* 620 cohort members were exposed only to PCE; the remainder were exposed to PCE and other dry-cleaning solvents (probably Stoddard solvent).
† 95% confidence interval excludes the null value (1.0).
‡ 99% confidence interval excludes the null value (1.0).

cleaning or were exposed to gasoline. The risk of pancreatic cancer increased fivefold for those employed more than 10 years in these occupations. Among 998 deceased white male former dry-cleaning workers exposed primarily to Stoddard solvent and other petroleum solvents, a recent study found elevated PMRs for lung, pancreatic, and kidney cancers.[16]

Katz and Jowett[15] found significantly elevated PMRs for cervical, genital, and kidney cancer, and excess (5 observed, 2.6 expected) bladder cancer in a mortality study of female laundry and dry-cleaning workers. Significantly elevated standardized mortality odds ratios for kidney (OR = 3.8, 95% CI = 1.9–7.6) and lung (OR = 1.7, 95% CI = 1.2–2.5) cancers were found by Duh and Asal[8] in a study of laundry and dry-cleaning workers. Stemhagen et al[20] found increased relative risk (RR) (RR = 2.50, 95% CI = 1.02–6.14) of primary liver cancer for men in laundry and dry cleaning. Smith et al[21] found no increased risk of bladder cancer in the "laundry and dry-cleaning workers" category.

There are no previous reports in the literature of the increase in intestinal (except rectal) cancer in dry-cleaning workers that we observed. However, a recent review suggests an association of occupational exposures to chlorinated hydrocarbons and colorectal cancer.[22] All but one of the 26 intestinal cancer deaths in our cohort involved cancer of the colon.

In our cohort, death rates for lung and kidney cancers (two of our a priori hypotheses) were elevated but not in significant excess. Liver cancer mortality (an a priori hypothesis based

on animal data) also was not elevated. Latency and duration patterns (Table 3) for esophageal, intestinal, pancreatic, and bladder cancers and for all cancer deaths were consistent with a hypothesis that the elevated cancer mortality was related to occupational exposure.

Smoking is considered a risk factor for esophageal, pancreatic, and bladder cancers. It is difficult to hypothesize a smoking pattern in the group with 20 years or more of latency and 5 years or more of employment that would produce SMRs of 5.40 for esophageal cancer, 2.22 for pancreatic cancer, and 6.50 for bladder cancer, but an SMR for lung cancer of 0.91. Axelson and Steenland[23] demonstrated that hypothetical populations with differing proportions of nonsmokers and moderate and heavy smokers could have a wide range of SMRs. However, because smokers have a fivefold higher risk of lung than of bladder cancer, a population with a bladder cancer SMR of 6.50 solely due to smoking should have a lung cancer SMR well over 20, not 0.91 (Table 3). That is, a smoking adjustment could not account for the significantly elevated risks of bladder, esophageal, and pancreatic cancer in the group with longest latency and duration of employment. Another risk factor for esophageal cancer is excess drinking.[24] If the drinking rate in this group were higher than in the US population, one would also expect an increase in deaths from cirrhosis of the liver. However, for the longer employment and latency group, the cirrhosis SMR is 1.28, although the esophageal cancer SMR is 5.40. Therefore, we cannot assume that the excess esophageal cancer mortality is due to either drinking or smoking.

When the dry-cleaning plants where cohort members worked were surveyed in the early 1980s, it was generally true that men were operators and women pressers, seamstresses, and counter personnel, who have lower solvent exposure. It might be supposed that cancer mortality rates would be higher among the male workers, who were more likely to have had high-exposure jobs. However, there was no evidence in this study that cancer mortality was higher among male than female workers (Table 2).

No reports in the literature associate tongue cancer with solvent or other environmental exposure; smoking, drinking, and chewing betel nuts are the major risk factors.[25] The excess tongue cancer in men in this cohort may be due to these lifestyle factors.

The difference in mortality rates between the PCE-only and PCE-plus subcohorts (Table 4) could be due to differences in type of exposure. Both subcohorts had a mean of approximately 6 years of PCE exposure (Table 1), and the PCE-plus subcohort had a mean of approximately 5 years of additional solvent exposure (to unidentified-as-such PCE and to other solvents). Because both subcohorts had comparable durations of PCE exposure, PCE cannot be ruled out as the cause of the excess mortality. In addition, among those with 20 or more years of latency and 5 or more years of employment in PCE shops only, the mortality rate for esophageal cancer is significantly elevated (SMR = 7.17, 95% CI = 1.92–19.82). Blair et al[14] also found a strong association between cumulative exposure to dry-cleaning solvents and the risk of esophageal cancer.

Some limitations should be noted. First, we updated vital status but not work histories for the cohort. We do not know which cohort members who were still working at the original study end date (December 31, 1982) continued to work in dry cleaning (and if so, with which solvents), switched occupations, or retired. However, it should be noted that most workers with continuous employment already would have worked at least 23 years by 1982, because one criterion for the cohort was 1 year of work in a PCE-only shop by 1960. In addition, everyone in the cohort has been followed since at least 1960, so living members of the cohort now have 30+ years latency. Therefore, additional work history information would not substantially change the composition of our duration of employment/latency categories.

A second limitation is that we cannot quantify exposure because we have no job titles or exposure measurements. There are known to be substantial differences in exposure by job title and by equipment type.[1] Third, we do not know to which solvents, in addition to PCE, members of the PCE-plus subcohort were exposed (although, for most of them, this exposure was probably to Stoddard solvent). Underestimated durations of employment and the inability to quantify exposure (even as high or low) would tend to bias results toward the null.

This cohort is experiencing significant excess cancer mortality. The results of this update confirm and strengthen the findings of Brown and Kaplan[2] of significant excess bladder cancer mortality and elevated digestive tract cancer mortality. The study confirms the esophageal cancer excess reported in one other study.[14] It also furnishes strong evidence of excess bladder and digestive tract cancer mortality in dry-cleaning workers. We plan to continue our investigation of this cohort with a cancer incidence study to ascertain cancers that may not have resulted in death. To determine whether the excess cancer risk in dry-cleaning workers can be attributed to a specific solvent, it will be necessary to study a large cohort with more comprehensive exposure information.

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