Exhibit 292

A 50-Year Mortality Follow-up of a Large Cohort of Oil Refinery Workers in Texas

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To investigate further the possible role of occupational exposures on mortality, an update of a large Texas petroleum refinery cohort was undertaken. Between 1937 and 1987, 6799 deaths were identified among 17,844 employees. Relative to the general population of Texas, the overall standardized mortality ratio (SMR) showed a statistically significant deficit, as did nine other cause-of-death categories. Statistically significant mortality excesses were found for bone cancer (SMR = 207.8; 95% confidence interval [CI], 110.6 to 355.3), acute lymphocytic leukemia (ALL) (SMR = 259.6; 95% CI, 112.1 to 511.5), and benign/unspecified neoplasms (SMR = 194.9; 95% CI, 129.5 to 281.7). However, none of these diseases demonstrated an exposure-response relationship with length of employment. Subcohort mortality analyses by sex and race groups, length of employment, interval since hire, period of hire, and pay status were also performed. Overall, the update findings do not indicate that any excess mortality occurred as a result of employment at the refinery.

In 1980, the Gulf Oil Corporation (which merged with Chevron in 1985) began publishing a series of epidemiologic reports on the mortality of current and former employees working at the Port Arthur refinery along the Texas Gulf Coast.[1–13] The Port Arthur cohort consisted of more than 16,000 refinery workers, and their mortality experience was observed from 1937 to 1978.

The results of these studies were generally favorable in that the overall mortality rate, and most cause-specific mortality rates, were lower than those of the general population. For the entire cohort, statistically significant deficits in mortality were observed for all causes, digestive cancer, esophageal cancer, rectal cancer, liver cancer, bladder cancer, lymphosarcoma and reticulosarcoma, heart disease, respiratory disease, and several other nonmalignant diseases. On the other hand, a statistically significant excess of bone cancer for the cohort was reported. However, a review of the causes of death of the workers as stated on their death certificates indicated that the excess was likely an artifact stemming from the coding rules of the eighth revision of the International Classification of Diseases, Adapted (ICDA).

The study presented here represents a 10-year update to the cohort of Port Arthur refinery employees. The update provides more precise estimates of mortality risk, and an opportunity for additional detailed analyses for some causes of death.

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* Dr Swencicki died unexpectedly on July 16, 1995, and will be missed.

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1076-2752/96/3805-0492$3.00/0

Methods and Materials

The original cohort consisted of employees who worked at least 1 day at the Port Arthur refinery between January 1, 1937 and January 1, 1978.[3] Subsequently, additional employees, who were hired after 1977 and worked for at least 1 day at the refinery, were enrolled in the study.[8] For purposes of the cohort update presented here, the population base consisted of Gulf employees who had worked at the Port Arthur refinery any time between January 1, 1937 and December 31, 1983.

The vital status of the cohort was updated from the end of the original study period (January 1, 1978) through December 31, 1987. Sources for vital status determination of the expanded cohort included Gulf's personnel and annuitant record systems, the Texas Department of Motor Vehicles, the Social Security Administration, and the National Death Index.

The updated cohort consists of 17,844 individuals, of which 6799 had died as of the end of the study (December 31, 1987). For 347 deceased cohort members (5.1% of all deaths), no death certificates could be found, but the dates of death were known. These deaths were not included in any cause-specific mortality analyses. All deaths were coded to the eighth revision of the ICDA codes.

The analysis was based on cause-specific standardized mortality ratios (SMRs) using the general Texas population rates as the reference. Because most other refinery studies are based on a comparison to the US general population, we also carried out one analysis for the entire cohort by using the US general population as the reference. These reference rates were also based on the ICDA eighth revision. Mortality analyses were performed using the OCMAP computer program.[14]

Because of the a priori interest in cancers of the lymphatic and hematopoietic tissues and the previous leukemia cell-type analysis of the cohort,[8] we conducted additional analyses for cell-type specific leukemias, non-Hodgkin's lymphoma, and multiple myeloma for the male cohort members. Age-specific leukemia cell-type mortality rates for US white males for the period 1969 to 1977,[15] were used in the calculation. For non-Hodgkin's lymphoma and multiple myeloma, age-specific mortality rates for US white males, 1950 to 1980, compiled by the National Cancer Institute[16] were used. Because no similar rates were available for nonwhite males, these rates were used for the entire male subcohort.

The following SMR analyses were performed on the cohort: total cohort, subcohorts stratified by sex and race, length of employment, interval since hire, period of hire, and pay status. The rationale for these analyses is as follows. Length of employment serves as an indirect measure for potential refinery exposures. Interval since hire analysis follows from the observation that chronic diseases typically require a sufficiently long period (latency) after exposure to develop and become clinically apparent; interval since hire is used as a surrogate for latency. With regard to period of hire, several investigators[13,17–19] have reported adverse health effects for workers hired during the second World War period (approximately 1940 to 1945). They also reported that those hired before, after, or during the war years likely experienced different exposure intensities (eg, higher before 1940 and lower after 1945) and exposure durations (eg, longer before 1940 and shorter in the 1940 to 1945 period). These differences in exposure resulted from improved engineering controls and personal protective equipment, as well as lowering of regulatory exposure standards. Thus, stratification on period of hire provides a means of assessing time-related exposure risks.

Finally, analysis by pay status provides another indirect way to assess the effects of potential refinery exposures. The presumption here is that hourly employees were/are more likely to be exposed at levels higher than salaried workers because of the nature of their respective jobs.

Statistical tests for trend were conducted across length of employment strata using the method described by Breslow and Day.[20] The result of the trend test is expressed in terms of chi-square (χ^2) with one degree of freedom (1 df).

Results

The 17,844 cohort members accrued a total of 526,387 person-years of observation (Table 1). Eighty-nine percent (12,608) of the cohort members are men, 79% of whom are white. Of the women, nearly 89% are white. As of the end of the study period, 38% of the cohort had died, and death certificates were obtained for 95% of the decedents.

The duration of employment at the refinery ranged from 3 days to 54.6 years, with a median duration of 12.4 years for men and 1.8 years for women (Table 1). Most cohort members have been followed for a considerable time. For men, the median interval since hire was 35.6 years, whereas that for women was 31.9 years (Table 1).

Using Texas death rates as the reference, about 7% fewer deaths were observed than expected (Table 2). The resulting SMR, 92.7, was statistically significant. Of the 37 cause-of-death categories presented, ten additional categories showed statistically significant deficits. These categories include cancer of the biliary tract and liver, lymphosarcoma and reticulosarcoma, cerebrovascular disease, heart disease, nonmalignant respiratory disease, and external causes of death (eg, accidents and injuries).

On the other hand, a few significant mortality excesses were found. As reported previously in the original cohort, a significant SMR for bone cancer persisted (SMR = 207.8; 95% confidence interval [CI],

TABLE 1
Demographic, Vital Status, and Employment Characteristics for All Cohort Members

Characteristic	Men	Women	Total
Population Size (%)	15855 (89)	1989 (11)	17844 (100)
Person-Years of Follow-up	474875	51512	526387
Race Distribution (%)			
White	79.5	89.4	80.6
Nonwhite	20.5	10.6	19.4
Black	17.1	5.9	15.8
Other and Unknown	3.4	4.7	3.6
Vital Status (as of 12/31/87) (%)			
Alive	52.4	55.0	52.7
Dead	41.1	13.9	38.1
Unknown	6.5	31.1*	9.2
Employment Duration (%)			
<1 year	22.2	41.3	24.3
1 to 9 years	23.6	40.3	25.4
10 to 19 years	14.7	9.7	14.1
≥20 years	39.6	8.7	36.2
Average (years)	16.7	5.8	15.5
Range	3 days to 54.6 years	3 days to 44.7 years	3 days to 54.6 years
Interval Since Hire† (%)			
<10 years	10.2	29.6	12.3
10 to 19 years	15.5	11.3	15.0
20 to 29 years	9.9	6.5	9.5
30 to 39 years	24.6	16.0	23.6
≥40 years	39.8	36.7	39.5
Average (years)	33.2	26.3	32.4
Range	3 days to 77.5 years	3 days to 72.0 years	3 days to 77.5 years
Year of Hire (%)			
1900 to 1919	5.8	0.2	5.1
1920 to 1949	60.3	70.6	61.5
1950 to 1969	18.7	11.2	17.8
1970 to 1987	15.2	18.0	15.6

* Of the women with an unknown vital status, over 88% had retired, left the company, or been transferred on or before 12/31/60, making tracing nearly impossible; almost one-third were lost to follow-up during the period 1940 to 1945.

† Interval since initial hire is the period between hire date and the earlier of date of death, date of last contact, or end of study.

110.6 to 355.3). A significant excess was also observed for the category "benign and unspecified neoplasms" (SMR = 194.9; 95% CI, 129.5 to 281.7). Although many different sites are included in this category, 17 of the 28 deaths in this category involved the brain. In the US general population, approximately 68% of the deaths in this broad category are brain tumors.[21] Applying 68% to the expected number of 14.4 in Table 2, an estimate of 9.8 deaths from benign brain tumor could be expected. The corresponding SMR was estimated to be approximately 173.5 (17 observed/9.8 expected; 95% CI, 100.8 to 277.6), which is borderline significant.

Because of the use of asbestos at the refinery in the past, we also examined mortality from causes known to be associated with it. With respect to malignant diseases, asbestos is a known cause of both lung cancer and mesothelioma. Table 2 shows that the lung cancer rate was not elevated (SMR = 92.9; 95% CI, 83.4 to 101.2).

Regarding mesothelioma, the eighth revision of the ICDA, which was used to code all deaths in the study, does not recognize a single code for this disease. Instead, depending on the wording on the death certificate, mesothelioma could be coded as a malignant respiratory cancer (ICDA codes 162.1, 163, 163.0, or 163.9), a malignant neoplasm without specification of site (ICDA codes 199, 199.0, or 199.1), or a benign respiratory disease (ICDA codes 212.3, 212.4, or 228). Death certificates with any of these codes as either the underlying or contributing cause of death were manually reviewed to identify all mesotheliomas (malignant or benign). Six deaths were coded as malignant mesotheliomas. Age-specific malignant mesothelioma mortality rates were not available for either the general US or Texas populations. However, because malignant mesothelioma is a rapidly fatal disease, incidence rates were used to estimate the expected number of deaths. These rates were derived from 1975 to 1979 data in the SEER Program,[22] based on microscopically confirmed diagnoses and excluding mesotheliomas that were specified as benign. For the Port Arthur cohort, 5.9 malignant

TABLE 2
Cause-Specific SMRs for All Cohort Members*

Cause of Death (ICDA 8th Revision Codes)	Observed	Reference: Texas General Population				Reference: US General Population			
		Expected	SMR	95% Confidence Interval		Expected	SMR	95% Confidence Interval	
				Lower	Upper			Lower	Upper
All Causes of Death (001 to 999)	6799	7336.0	92.7†	90.5	94.9	7541.1	90.2†	88.0	92.3
All Malignant Neoplasms (140 to 209)	1482	1444.3	102.6	97.4	108.0	1528.6	97.0	92.1	102.0
Cancer of Buccal Cavity and Pharynx (140 to 149)	36	40.9	87.9	61.6	121.8	45.0	80.0	56.0	110.8
Cancer of Digestive Organs and Peritoneum (150 to 159)	377	371.7	101.4	91.4	112.2	435.9	86.5†	78.0	95.7
Cancer of Esophagus (150)	23	34.1	67.5	42.8	101.3	44.5	51.6†	32.7	77.5
Cancer of Stomach (151)	95	80.2	118.5	95.9	144.9	92.5	102.7	83.1	125.6
Cancer of Large Intestine (153)	117	106.4	110.0	90.9	131.8	134.3	87.1	72.0	104.4
Cancer of Rectum (154)	26	26.3	98.8	64.5	144.8	43.5	59.8†	39.1	87.7
Cancer of Biliary Passages and Liver (155 to 156)	13	31.0	41.9†	22.3	71.6	26.6	48.8†	26.0	83.4
Cancer of Pancreas (157)	94	80.8	116.4	94.1	142.4	80.6	116.7	94.3	142.8
Cancer of Respiratory System (160 to 163)	448	485.5	92.3	83.9	101.2	482.2	92.9	84.5	101.9
Cancer of the Bronchus, Trachea, Lung (162)	423	459.8	92.0	83.4	101.2	454.2	93.1	84.5	102.4
Cancer of Breast (174)	22	17.6	125.4	78.6	189.8	21.0	104.8	65.7	158.7
All Uterine Cancers (Women only) (180 to 182)	7	6.7	104.2	41.9	214.7	7.0	99.9	40.1	205.8
Cancer of Prostate (Men only) (185)	126	131.0	96.2	80.1	114.5	136.4	92.4	77.0	110.0
Cancer of Kidney (189)	40	31.3	127.9	91.4	174.2	32.7	122.4	87.5	166.7
Cancer of Bladder and Other Urinary Organs (188, 189.9)	25	34.8	71.9	46.5	106.1	44.7	55.9†	36.2	82.5
Malignant Melanoma of Skin (172 except scrotum)	21	18.7	112.2	69.5	171.5	14.7	142.7	88.4	218.2
Cancer of Central Nervous System (191 to 192)	39	33.1	117.7	83.7	160.9	35.2	110.8	78.8	151.5
Cancer of Bone (170)	13	6.3	207.8‡	110.6	355.3	6.6	198.4‡	105.6	339.3
Cancer of All Lymphatic, Haematopoietic Tissue (200 to 209)	138	131.7	104.8	88.0	123.8	135.6	101.8	85.5	120.3
Lymphosarcoma and Reticulosarcoma (200)	13	23.0	56.5‡	30.1	96.5	25.4	51.2‡	27.3	87.6
Hodgkin's Disease (201)	18	12.7	141.3	83.7	223.3	14.2	127.1	75.3	200.9
Leukemia and Aleukemia (204 to 207)	57	55.9	102.0	77.3	132.2	55.0	103.7	78.6	134.4
Cancer of All Other Lymphopoietic Tissue (202 to 203, 208 to 209)	50	40.1	124.7	92.6	164.5	41.1	121.7	90.3	160.4
Benign Neoplasms/Neoplasms of Unspecified Nature (210 to 239)	28	14.4	194.9†	129.5	281.7	18.9	148.4	98.6	214.4
Diabetes Mellitus (250)	107	101.2	105.7	86.7	127.8	115.9	92.3	75.7	111.6
Cerebrovascular Disease (430 to 438)	502	600.5	83.6†	76.4	91.2	584.4	85.9†	78.6	93.8
All Heart Disease (390 to 398, 400.1, 400.9, 402, 404, 410 to 414, 420 to 429)	2534	2784.9	91.0†	87.5	94.6	3008.5	84.2†	81.0	87.6
Ischemic Heart Disease (410 to 414)	1994	2283.3	87.3†	83.5	91.2	2650.5	75.2†	72.0	78.6
Hypertension with Heart Disease (400.1, 400.9, 402, 404)	72	63.7	113.0	88.4	142.3	74.6	96.5	75.5	121.5
Hypertension without Heart Disease (400, 400.2, 400.3, 401, 403)	32	29.9	107.2	73.3	151.3	32.5	98.3	67.3	138.8
Nonmalignant Respiratory Disease (460 to 519)	346	469.4	73.7†	66.1	81.9	494.7	69.9†	62.8	77.7
Cirrhosis of the Liver (571)	79	121.9	64.8†	51.3	80.8	160.5	49.2†	39.0	61.3
All External Causes of Death (E800 to E999)	547	759.3	72.0†	66.1	78.3	657.8	83.2†	76.3	90.4
Motor Vehicle Accidents (E810 to E823)	169	239.6	70.5†	60.3	82.0	190.3	88.8	75.9	103.3
Suicides (E950 to E959)	111	118.2	93.9	77.2	113.1	120.0	92.5	76.1	111.4

* Number of Persons at Risk = 17,844; Person-Years = 526,386.7.
† Significant at 1% Level.
‡ Significant at 5% Level.

mesothelioma deaths would have been expected. The resultant SMR was 101.7 (95% CI, 37.3 to 221.6). In addition, three deaths were coded as benign mesotheliomas.

Asbestosis is the term for pulmonary fibrosis caused by exposure to asbestos, or, more correctly, in persons with a documented history of occupational exposure to asbestos. A thorough review of all death certificates in the study did not reveal any with the underlying cause of death as asbestosis (ICDA 515.2), although ten deaths were the result of pulmo-

nary fibrosis (ICDA 515.x - 517.x). These ten deaths did not represent an increase in the occurrence of generalized pulmonary fibrosis: the expected number of deaths in the study is 28.6, yielding an SMR of 35.0 (95% CI, 16.8 to 64.4). The expected number is based on unpublished data from the National Center for Health Statistics for the general US population.

Because most refinery studies are based on a comparison to the US general population, an additional analysis for the entire cohort based on US death rates was carried out (Table 2). The results were generally similar to those based on Texas death rates, although there were some differences. Several additional significant deficits were observed (eg, cancer of digestive organs and peritoneum, esophageal cancer, rectal cancer, bladder cancer). In addition, the SMR for benign and unspecified neoplasms was no longer statistically significant. Within this category, the number of expected benign brain tumor deaths was estimated to be 12.9, and the corresponding SMR was 131.7 (95% CI, 76.5 to 210.7). All other analyses in this report were based on Texas death rates, unless otherwise specified.

Table 3 presents cause-specific SMRs among white men, nonwhite men, and white women. Because white men accounted for 71% of the entire cohort, their mortality experience generally paralleled that of the entire cohort. Their overall SMR was significantly lower than expected (SMR = 96.6), whereas the same causes showing significantly elevated SMRs for the entire cohort, plus hypertension without heart disease (SMR = 167.3), were also significantly elevated. A few additional significant mortality deficits were observed for white men, including cancer of the digestive organs and peritoneum (SMR = 86.5), esophageal cancer (SMR = 51.6), bladder cancer (SMR = 55.9), and rectal cancer (SMR = 59.8).

The analysis for nonwhite men, based on 3247 individuals and over 88,000 person-years of follow-up, also showed a significant deficit in overall mortality (SMR = 78.4). No cause-specific SMRs were significantly elevated for nonwhite men. On the other hand, significant deficits were reported for cancer of the large intestine, lung cancer, all heart disease, nonmalignant respiratory disease, and external causes of death.

Among the 1778 white women in the cohort, 267 deaths were observed, yielding an SMR of 111.3, which was not statistically significant. Two causes showed significant elevations: all malignant neoplasms (89 observed, SMR = 126.5) and benign and unspecified neoplasms (four observed, SMR = 420.5). The increase in all malignant neoplasms was driven by cancers of the large intestine, lung, and breast. Although each of these showed an elevated SMR, none were statistically significant.

No analyses are presented for nonwhite women because only ten deaths were observed among the 211 women in this subcohort. There was no clustering among the causes of death.

Table 4 presents a mortality analysis by length of employment for the entire cohort. Mortality from all causes combined showed a significantly decreasing trend by length of employment ($\chi^2_{\text{trend (1 df)}} = 32.2$, $P = .00$). Four cause-specific SMRs were significantly elevated in the 20- to 29-year stratum, but no trend with length of employment was observed: stomach cancer (SMR = 156.7; $\chi^2_{\text{trend (1 df)}} = .49$, $P = 0.48$), lymphatic and hematopoietic tissue (SMR = 152.6; $\chi^2_{\text{trend (1 df)}} = .49$, $P = .49$), leukemia (SMR = 222.7; $\chi^2_{\text{trend (1 df)}} = 1.76$, $P = .18$), and hypertension with heart disease (SMR = 214.3; $\chi^2_{\text{trend (1 df)}} = 3.23$, $P = .07$). Benign and unspecified neoplasms (SMR = 257.9) and hypertension without heart disease (SMR = 197.9) also showed significant excesses in the 30+-year group. Hypertension without heart disease demonstrated a positive trend ($\chi^2_{\text{trend (1 df)}} = 9.95$, $P = .02$), whereas benign and unspecified neoplasms did not ($\chi^2_{\text{trend (1 df)}} = 1.25$, $P = .26$).

Because bone cancer had a significantly elevated SMR in the entire cohort analysis, we performed a trend test on it as well, even though no SMR in any of the strata was significantly elevated in the length of employment analysis. The result indicated that no trend was present ($\chi^2_{\text{trend (1 df)}} = .21$, $P = .65$).

Analysis by interval since hire (Table 5) shows numerous cause-of-death categories, both cancers and noncancers, with significant deficits in various intervals since hire. No significantly elevated SMRs were found for any cause in employees with an interval since hire of less than 30 years. Several cause-of-death categories showed significantly elevated SMRs after at least a 30-year interval of time, but none had a positive trend with length of employment: all malignant neoplasms ($\chi^2_{\text{trend (1 df)}} = 3.82$, $P = .05$; borderline significant inverse trend), cancers of the stomach ($\chi^2_{\text{trend (1 df)}} = .49$, $P = .48$), central nervous system ($\chi^2_{\text{trend (1 df)}} = .00$, $P = .99$), bone ($\chi^2_{\text{trend (1 df)}} = .21$, $P = .65$), benign and unspecified neoplasms ($\chi^2_{\text{trend (1 df)}} = 1.25$, $P = .26$), hypertension with heart disease ($\chi^2_{\text{trend (1 df)}} = 3.23$, $P = .07$), and suicides ($\chi^2_{\text{trend (1 df)}} = .15$, $P = .70$).

With regard to period-of-hire analysis, about 175,000 person-years of follow-up accrued in each of the three strata studied: pre-1940, 1940 through 1945, and after-1945. However, there were many differences among the strata. For example, a higher percentage of women (18.5%) were hired in the 1940 through 1945 period (the "war" years) as compared to either the earlier period (3.2%) or the later period (8.9%); employees hired in the 1940 to 1945 period worked at the refinery for a median of 0.9 years vs 30.7 years in the pre-1940 group and 8.3 years for

TABLE 3
Cause-Specific SMRs by Race and Sex

Cause of Death (ICDA 8th Revision Codes)	White Men (*n* = 12,608 Persons at Risk; Person-Years = 386,469.8)				Nonwhite Men (*n* = 3247 Persons at Risk; Person-Years = 88404.7)				White Women (*n* = 1778 Persons at Risk; Person-Years = 47910.7)			
	Obs	SMR	95%	CI	Obs	SMR	95%	CI	Obs	SMR	95%	CI
All Causes of Death (001 to 999)	5180	96.6†	94.0	99.3	1342	78.4†	74.3	82.8	267	111.3	98.4	125.5
All Malignant Neoplasms (140 to 209)	1096	104.8	98.7	111.2	295	91.1	81.0	102.1	89	126.5†	101.6	155.7
Cancer of Buccal Cavity and Pharynx (140 to 149)	27	86.9	57.3	126.4	7	79.6	32.0	164.1	2	198.5	24.0	717.1
Cancer of Digestive Organs and Peritoneum (150 to 159)	271	104.9	92.8	118.2	86	88.1	70.5	108.8	20	137.4	83.9	212.2
Cancer of Esophagus (150)	11	56.2	28.1	100.6	11	79.4	39.7	142.1	1	175.8	4.4	979.8
Cancer of Stomach (151)	58	114.1	86.7	147.5	35	129.3	90.0	179.8	2	97.3	11.8	351.3
Cancer of Large Intestine (153)	90	113.8	91.5	139.9	18	85.8	50.8	135.6	9	152.2	69.6	288.8
Cancer of Rectum (154)	22	114.5	71.7	173.3	1	16.7†	0.4	93.2	3	291.3	60.1	851.4
Cancer of Biliary Passages and Liver (155 to 156)	10	47.3†	22.7	86.9	3	36.2	7.5	105.8	0		0.0	244.5
Cancer of Pancreas (157)	73	122.4	95.9	153.9	17	95.7	55.7	153.2	4	129.1	35.2	330.6
Cancer of Respiratory System (160 to 163)	352	94.3	84.7	104.7	80	79.6†	63.1	99.1	15	132.6	74.2	218.7
Cancer of the Bronchus, Trachea, Lung (162)	333	94.1	84.3	104.8	75	79.4†	62.5	99.5	15	137.1	76.7	226.2
Cancer of Breast (174)	0		0.0	327.1	1	179.2	4.5	998.5	20	133.7	81.7	206.5
All Uterine Cancers (Women only) (180 to 182)	0				0				7	117.4	47.2	241.8
Cancer of Prostate (Men only) (185)	90	103.7	83.4	127.5	36	81.4	57.0	112.8	0			
Cancer of Kidney (189)	27	107.2	70.7	156.0	10	202.1	96.9	371.7	3	277.5	57.3	810.9
Cancer of Bladder and Other Urinary Organs (188, 189.9)	17	64.5	37.6	103.2	7	90.3	36.3	186.1	1	165.9	4.1	924.5
Malignant Melanoma of Skin (172 except scrotum)	21	124.1	76.8	189.7	0		0.0	578.6	0		0.0	320.9
Cancer of Central Nervous System (191 to 192)	32	114.0	78.0	160.9	4	140.1	38.2	358.7	3	140.2	28.9	409.6
Cancer of Bone (170)	10	217.2†	104.1	399.4	2	146.0	17.7	527.3	1	386.1	9.7	2151.5
Cancer of All Lymphatic, Haematopoietic Tissue (200 to 209)	113	111.7	92.1	134.4	20	83.1	50.8	128.4	5	80.7	26.2	188.3
Lymphosarcoma and Reticulosarcoma (200)	9	48.8†	22.3	92.6	3	88.4	18.2	258.4	1	87.4	2.2	487.3
Hodgkin's Disease (201)	14	137.4	75.1	230.5	4	200.5	54.6	513.4	0		0.0	691.0
Leukemia and Aleukemia (204 to 207)	52	117.6	87.8	154.2	4	44.3	12.1	113.4	1	40.7	1.0	226.7
Cancer of All Other Lymphopoietic Tissue (202 to 203, 208 to 209)	38	134.6	95.2	184.7	9	93.4	42.7	177.4	3	145.6	30.0	425.4
Benign Neoplasms/Neoplasms of Unspecified Nature (210 to 239)	17	172.7†	100.6	276.6	7	201.6	81.0	415.4	4	420.5†	114.6	1076.8
Diabetes Mellitus (250)	70	100.4	78.3	126.9	31	125.8	85.5	178.6	6	100.4	36.8	218.5
Cerebrovascular Disease (430 to 438)	349	87.2†	78.3	96.8	137	77.5‡	65.0	91.6	16	77.5	44.3	125.9
All Heart Disease (390 to 398, 400.1, 400.9, 402, 404, 410 to 414, 420 to 429)	2026	95.2†	91.1	99.4	441	75.7‡	68.8	83.1	64	96.3	74.1	122.9
Ischemic Heart Disease (410 to 414)	1649	90.8‡	86.4	95.3	297	72.1‡	64.1	80.8	45	90.6	66.1	121.3
Hypertension with Heart Disease (400.1, 400.9, 402, 404)	42	129.6	93.4	175.1	29	100.6	67.4	144.5	1	51.8	1.3	288.6
Hypertension without Heart Disease (400, 400.2, 400.3, 401, 403)	24	167.3†	107.2	248.9	8	54.7	23.6	107.7	0		0.0	561.2
Nonmalignant Respiratory Disease (460 to 519)	264	72.4‡	64.0	81.7	71	78.1†	61.0	98.5	10	76.1	36.5	140.0
Cirrhosis of the Liver (571)	65	67.6‡	52.2	86.1	11	55.0†	27.4	98.4	3	56.3	11.6	164.4
All External Causes of Death (E800 to E999)	433	81.1‡	73.6	89.1	93	45.6‡	36.8	55.9	20	103.1	63.0	159.3
Motor Vehicle Accidents (E810 to E823)	137	76.0‡	63.8	89.8	23	44.6‡	28.3	66.9	9	123.8	56.6	235.0
Suicides (E950 to E959)	96	91.3	74.0	111.5	9	105.0	48.0	199.2	6	134.8	49.5	293.5

* Obs, observed; SMR, standardized mortality ratio; 95% CI, 95% confidence interval. Blank spaces indicate that the SMR was not calculated where no deaths were observed.
† Significant at 5% Level.
‡ Significant at 1% Level.

TABLE 4
Cause-Specific SMRs for All Cohort Members Stratified by Length of Employment

Cause of Death (ICDA 8th Revision Codes)	<1 Year		1 to 9 Years		10 to 19 Years		20 to 29 Years		30+ Years	
	Observed	SMR	Observed	SMR	Observed	SMR	Observed	SMR	Observed	SMR
All Causes of Death (001 to 999)	1346	109.8*	1135	95.8	784	87.2*	1167	87.0*	2367	88.2*
All Malignant Neoplasms (140 to 209)	305	114.7†	242	102.4	144	88.3	270	112.6	521	96.6
Cancer of Buccal Cavity and Pharynx (140 to 149)	11	148.9	4	61.7	4	82.0	7	92.2	10	68.5
Cancer of Digestive Organs and Peritoneum (150 to 159)	67	108.5	56	98.9	32	74.1	81	119.8	141	98.9
Cancer of Esophagus (150)	8	136.4	2	35.0	3	78.2	3	50.2	7	55.3
Cancer of Stomach (151)	13	116.3	11	98.8	8	77.9	27	156.7†	36	118.6
Cancer of Large Intestine (153)	19	99.7	18	107.8	10	87.8	23	134.1	47	111.6
Cancer of Rectum (154)	2	46.7	3	76.7	5	159.9	5	100.6	11	109.8
Cancer of Biliary Passages and Liver (155 to 156)	3	52.2	2	38.5	0		4	86.0	4	33.0†
Cancer of Pancreas (157)	20	142.2	18	146.8	5	55.0	19	135.8	32	102.0
Cancer of Respiratory System (160 to 163)	104	109.0	77	94.8	52	99.0	59	78.5	156	86.1
Cancer of the Bronchus, Trachea, Lung (162)	101	111.0	72	93.3	49	98.9	57	80.9	144	83.9†
Cancer of Breast (174)	6	83.3	11	197.7	1	61.9	1	65.6	3	182.8
All Uterine Cancers (Women only) (180 to 182)	2	74.0	1	43.1	0		2	360.7	2	437.8
Cancer of Prostate (Men only) (185)	14	88.3	12	80.0	10	76.6	25	109.8	65	101.1
Cancer of Kidney (189)	9	147.9	6	115.1	4	110.2	7	134.2	14	125.9
Cancer of Bladder and Other Urinary Organs (188, 189.9)	3	59.6	5	111.3	2	52.3	4	64.4	11	72.3
Malignant Melanoma of Skin (172 except scrotum)	5	117.6	4	103.1	4	154.7	2	67.2	6	119.5
Cancer of Central Nervous System (191 to 192)	12	154.3	6	86.1	4	87.1	6	113.3	11	129.4
Cancer of Bone (170)	2	181.6	3	271.1	2	244.8	3	242.9	3	150.3
Cancer of All Lymphatic, Haematopoietic Tissue (200 to 209)	25	100.5	23	99.0	10	61.1	33	152.6†	47	103.0
Lymphosarcoma and Reticulosarcoma (200)	3	68.6	3	75.4	2	64.7	3	72.1	2	26.9†
Hodgkin's Disease (201)	3	110.7	5	170.5	1	47.3	4	185.1	5	176.8
Leukemia and Aleukemia (204 to 207)	8	79.0	5	52.4	5	73.6	21	222.7*	18	90.2
Cancer of All Other Lymphopoietic Tissue (202 to 203, 208 to 209)	11	143.4	10	147.3	2	45.9	5	85.5	22	142.7
Benign Neoplasms/Neoplasms of Unspecified Nature (210 to 239)	3	108.8	4	148.3	4	216.6	5	207.2	12	257.9*
Diabetes Mellitus (250)	12	69.6	17	104.2	11	90.7	19	107.4	48	127.0
Cerebrovascular Disease (430 to 438)	61	80.9	55	75.1†	49	73.3†	113	90.6	224	86.1†
All Heart Disease (390 to 398, 400.1, 400.9, 402, 404, 410 to 414, 420 to 429)	439	100.8	357	91.5	281	86.0†	449	83.6*	1008	92.0*
Ischemic Heart Disease (410 to 414)	359	101.7	293	94.6	213	78.8*	347	76.6*	782	87.1*
Hypertension with Heart Disease (400.1, 400.9, 402, 404)	7	76.9	6	61.5	5	65.9	26	214.3*	28	111.3
Hypertension without Heart Disease (400, 400.2, 400.3, 401, 403)	1	25.8	2	42.9	5	106.5	4	61.4	20	197.9*
Nonmalignant Respiratory Disease (460 to 519)	82	113.7	55	85.0	48	91.5	47	56.1*	114	58.1*
Cirrhosis of the Liver (571)	23	86.1	14	57.7†	3	17.1*	12	52.4†	27	88.6
All External Causes of Death (E800 to E999)	138	81.8†	153	70.1*	77	59.1*	76	66.6*	103	80.6†
Motor Vehicle Accidents (E810 to E823)	39	69.2†	50	70.0*	19	47.6*	30	87.8	31	82.1
Suicides (E950 to E959)	32	117.3	24	80.0	14	73.1	12	63.7	29	126.4

* Significant at 1% Level.
† Significant at 5% Level.

TABLE 5
Cause-Specific SMRs for All Cohort Members Stratified by Years Since Hired

Cause of Death (ICDA 8th Revision Codes)	<10 Years		10 to 19 Years		20 to 29 Years		30 to 39 Years		40+ Years	
	Observed	SMR	Observed	SMR	Observed	SMR	Observed	SMR	Observed	SMR
All Causes of Death (001 to 999)	269	76.2*	567	83.2*	1128	81.9*	1949	96.8	2886	99.1
All Malignant Neoplasms (140 to 209)	26	71.7	87	84.5	247	92.6	483	107.2	639	108.7†
Cancer of Buccal Cavity and Pharynx (140 to 149)	1	108.3	4	112.4	9	97.8	10	73.7	12	87.7
Cancer of Digestive Organs and Peritoneum (150 to 159)	5	58.6	18	65.3	71	100.1	122	105.7	161	107.8
Cancer of Esophagus (150)	0		0		5	70.8	8	66.7	10	82.2
Cancer of Stomach (151)	0		7	90.2	20	113.8	37	152.4†	31	110.2
Cancer of Large Intenstine (153)	1	46.1	7	115.4	15	90.3	34	106.3	60	121.0
Cancer of Rectum (154)	1	135.8	1	46.4	5	96.8	3	37.8	16	154.9
Cancer of Biliary Passages and Liver (155 to 156)	0		0		6	120.3	3	30.4†	4	28.4*
Cancer of Pancreas (157)	3	236.1	3	56.1	19	122.9	32	124.5	37	112.1
Cancer of Respiratory System (160 to 163)	6	93.4	22	76.5	65	70.2*	156	94.2	199	103.7
Cancer of the Bronchus, Trachea, Lung (162)	6	102.9	20	74.9	61	70.0*	148	94.1	188	102.8
Cancer of Breast (174)	1	115.0	1	44.5	5	104.9	9	149.3	6	165.0
All Uterine Cancers (Women only) (180 to 182)	0		1	69.5	0		3	173.5	3	312.6
Cancer of Prostate (Men only) (185)	2	352.5	1	31.9	11	86.0	25	75.3	87	107.0
Cancer of Kidney (189)	1	128.1	4	160.8	7	108.6	14	137.3	14	123.2
Cancer of Bladder and Other Urinary Organs (188, 189.9)	1	232.1	1	55.4	2	37.7	5	50.3	16	92.4
Malignant Melanoma of Skin (172 except scrotum)	1	64.1	2	72.2	4	92.6	6	120.6	8	157.2
Cancer of Central Nervous System (191 to 192)	0		4	80.9	7	83.8	18	184.2†	10	132.1
Cancer of Bone (170)	1	164.9	2	260.2	1	69.4	8	454.1*	1	59.6
Cancer of All Lymphatic, Haematopoietic Tissue (200 to 209)	3	42.2	14	105.5	24	96.7	44	119.5	53	106.6
Lymphosarcoma and Reticulosarcoma (200)	0		1	33.8	4	73.3	6	90.8	2	29.8
Hodgkin's Disease (201)	0		5	183.5	4	125.9	6	221.9	3	130.1
Leukemia and Aleukemia (204 to 207)	3	91.4	6	109.5	8	79.8	19	127.1	21	94.9
Cancer of All Other Lymphopoietic Tissue (202 to 203, 208 to 209)	0		2	94.9	8	130.1	13	103.7	27	145.2
Benign Neoplasms/Neoplasms of Unspecified Nature (210 to 239)	1	104.3	4	242.5	3	101.9	10	259.6†	10	201.6
Diabetes Mellitus (250)	1	27.6	5	58.5	12	66.2	37	127.5	52	124.2
Cerebrovascular Disease (430 to 438)	6	54.1	28	75.8	64	67.2*	126	80.4†	278	92.6
All Heart Disease (390 to 398, 400.1, 400.9, 402, 404, 410 to 414, 420 to 429)	33	53.7*	164	76.4*	397	75.1*	765	95.0	1175	100.0
Ischemic Heart Disease (410 to 414)	25	52.0*	141	77.7*	332	73.3*	606	91.3†	890	95.0
Hypertension with Heart Disease (400.1, 400.9, 402, 404)	0		3	59.3	12	111.8	30	159.5†	27	98.0
Hypertension without Heart Disease (400, 400.2, 400.3, 401, 403)	1	67.8	2	45.1	2	29.7	11	154.2	16	158.5
Nonmalignant Respiratory Disease (460 to 519)	7	66.2	19	66.9	43	61.5*	95	76.4*	182	77.1*
Cirrhosis of the Liver (571)	2	30.2	4	21.8*	21	58.2*	31	84.0	21	87.8
All External Causes of Death (E800 to E999)	103	57.1*	126	72.3*	117	68.6*	104	79.4†	97	93.9
Motor Vehicle Accidents (E810 to E823)	32	49.8*	42	77.2	41	77.5	31	78.3	23	80.7
Suicides (E950 to E959)	11	54.0†	14	56.1†	31	106.1	20	80.0	35	187.1*

* Significant at 1% Level.
† Significant at 5% Level.

TABLE 6
Cause-Specific SMRs for All Cohort Members by Period of Hire

Cause of Death (ICDA 8th Revision Codes)	Hired < 1940*		Hired 1940 to 1945†		Hired > 1945‡	
	Observed	SMR	Observed	SMR	Observed	SMR
All Causes of Death (001 to 999)	3827	91.7§	2191	101.6	781	77.7§
All Malignant Neoplasms (140 to 209)	791	103.9	505	106.6	186	88.9
Cancer of Buccal Cavity & Pharynx (140 to 149)	18	83.2	11	83.6	7	113.9
Cancer of Digestive Organs & Peritoneum (150 to 159)	218	102.9	114	99.6	45	99.1
Cancer of Esophagus (150)	10	58.8	7	60.4	6	109.6
Cancer of Stomach (151)	60	118.0	22	101.2	13	172.1
Cancer of Large Intestine (153)	69	118.4	37	108.4	11	78.6
Cancer of Rectum (154)	20	129.0	5	64.2	1	33.1
Cancer of Biliary Passages & Liver (155 to 156)	8	50.5‖	4	37.5‖	1	22.0
Cancer of Pancreas (157)	46	102.4	36	140.0	12	118.5
Cancer of Respiratory System (160 to 163)	230	98.2	172	101.1	46	56.7§
Cancer of the Bronchus, Trachea, Lung (162)	214	97.2	165	101.8	44	56.7§
Cancer of Breast (174)	5	133.4	12	115.2	5	147.7
All Uterine Cancers (Women only) (180 to 182)	4	257.8	3	75.9	0	
Cancer of Prostate (Men only) (185)	91	101.0	33	96.4	2	30.3
Cancer of Kidney (189)	16	102.7	12	115.9	12	225.1‖
Cancer of Bladder and Other Urinary Organs (188, 189.9)	20	89.4	4	40.5	1	39.5
Malignant Melanoma of Skin (172 except scrotum)	9	114.1	5	82.4	7	146.9
Cancer of Central Nervous System (191 to 192)	13	95.5	19	160.2	7	91.5
Cancer of Bone (170)	8	225.3	3	167.5	2	218.7
Cancer of All Lymphatic, Haematopoietic Tissue (200 to 209)	76	110.8	39	93.1	23	108.3
Lymphosarcoma and Reticulosarcoma (200)	6	48.7	4	54.6	3	88.4
Hodgkin's Disease (201)	12	205.2‖	5	122.6	1	35.5
Leukemia and Aleukemia (204 to 207)	32	105.2	15	88.6	10	117.7
Cancer of All Other Lymphopoietic Tissue (202 to 203, 208 to 209)	26	130.4	15	110.4	9	137.5
Benign Neoplasms/Neoplasms of Unspecified Nature (210 to 239)	16	218.8§	6	128.3	6	252.5
Diabetes Mellitus (250)	73	127.5	26	84.0	8	61.7
Cerebrovascular Disease (430 to 438)	358	87.5‖	110	73.2§	34	83.1
All Heart Disease (390 to 398, 400.1, 400.9, 402, 404, 410 to 414, 420 to 429)	1503	89.2§	774	96.8	257	85.3‖
Ischemic Heart Disease (410 to 414)	1170	83.0§	623	96.8	201	87.4
Hypertension with Heart Disease (400.1, 400.9, 402, 404)	54	145.9‖	15	82.4	3	35.2
Hypertension without Heart Disease (400, 400.2, 400.3, 401, 403)	28	147.9	3	36.6	1	36.7
Nonmalignant Respiratory Disease (460 to 519)	199	68.3§	129	95.9	18	41.3§
Cirrhosis of the Liver (571)	31	61.5§	32	76.7	16	53.8§
All External Causes of Death (E800 to E999)	206	70.4§	194	85.4‖	147	61.4§
Motor Vehicle Accidents (E810 to E823)	66	73.6‖	51	70.7‖	52	66.8§
Suicides (E950 to E959)	45	97.0	45	125.0	21	58.6‖

* Hired before 1/1/1940, $n = 5184$.
† Hired between 1/1/1940 and 12/31/1945, $n = 5029$.
‡ Hired after 12/31/1945, $n = 7631$.
§ Significant at 1% level.
‖ Significant at 5% level.

those hired after 1945; and the median interval since hire (to the earliest of death, loss to follow-up, or the end of the study period) exceeded 40 years for cohort members hired before 1945 and was nearly 22 years for those hired after 1945. The distribution of deaths was also nonuniform in that 56.3% occurred in those employees hired before 1940 vs 18.5% and 8.9% in those hired in the 1940 to 1945 period and in or after 1945, respectively.

Significant deficits in the all causes-of-death category were found for the pre-1940 stratum (SMR = 91.7) and the after-1945 stratum (SMR = 77.7) (Table 6). The SMR (101.6) was close to expected for those hired between 1940 and 1945. Eight additional causes of death showed significant deficits in both the pre-1940 and after-1945 strata. These compare to a total of four

TABLE 7
Cause-Specific SMRs for All Cohort Members by Pay Status

Cause of Death (ICDA 8th Revision Codes)	Hourly*		25 to 75% Salaried†		90 to 100% Salaried‡	
	Observed	SMR	Observed	SMR	Observed	SMR
All Causes of Death (001 to 999)	5926	96.5§	383	76.4§	455	71.7§
All Malignant Neoplasms (140 to 209)	1284	106.3‖	87	88.4	101	79.4‖
Cancer of Buccal Cavity and Pharynx (140 to 149)	30	87.0	3	104.8	3	89.9
Cancer of Digestive Organs and Peritoneum (150 to 159)	323	103.3	24	96.3	30	96.5
Cancer of Esophagus (150)	22	75.1	1	49.0	0	
Cancer of Stomach (151)	84	123.2	5	99.3	6	98.5
Cancer of Large Intestine (153)	98	111.0	11	147.0	8	81.4
Cancer of Rectum (154)	19	86.2	4	220.7	3	133.5
Cancer of Biliary Passages and Liver (155 to 156)	12	46.0§	0		1	37.5
Cancer of Pancreas (157)	79	116.6	3	53.3	12	176.2
Cancer of Respiratory System (160 to 163)	404	98.8	20	58.4‖	20	50.5§
Cancer of the Bronchus, Trachea, Lung (162)	381	98.4	19	58.6‖	19	50.4§
Cancer of Breast (174)	14	116.2	0		8	161.5
All Uterine Cancers (Females only) (180 to 182)	5	118.0	1	694.6	1	43.7
Cancer of Prostate (Males only) (185)	104	93.4	8	89.6	8	89.0
Cancer of Kidney (189)	36	138.1	3	133.1	1	36.2
Cancer of Bladder and Other Urinary Organs (188, 189.9)	22	75.2	2	78.7	1	37.0
Malignant Melanoma of Skin (172 except scrotum)	18	118.1	0		3	146.8
Cancer of Central Nervous System (191 to 192)	33	120.8	3	129.0	3	89.5
Cancer of Bone (170)	12	228.7‖	0		1	183.6
Cancer of All Lymphatic, Haematopoietic Tissue (200 to 209)	115	104.9	9	98.1	14	116.3
Lymphosarcoma and Reticulosarcoma (200)	7	36.5§	3	183.7	3	144.3
Hodgkin's Disease (201)	14	131.8	1	117.3	3	248.1
Leukemia and Aleukemia (204 to 207)	51	110.0	2	50.0	4	77.8
Cancer of All Other Lymphopoietic Tissue (202 to 203, 208 to 209)	43	128.4	3	111.5	4	111.0
Benign Neoplasms/Neoplasms of Unspecified Nature (210 to 239)	19	158.8	4	433.1‖	5	365.8‖
Diabetes Mellitus (250)	91	108.1	7	104.3	8	84.3
Cerebrovascular Disease (430 to 438)	431	85.7§	37	92.8	30	59.0§
All Heart Disease (390 to 398, 400.1, 400.9, 402, 404, 410 to 414, 420 to 429)	2188	93.9§	148	74.3§	186	80.0§
Ischemic Heart Disease (410 to 414)	1704	89.3§	119	71.0§	163	85.6‖
Hypertension with Heart Disease (400.1, 400.9, 402, 404)	66	121.6	2	56.4	4	77.9
Hypertension without Heart Disease (400, 400.2, 400.3, 401, 403)	21	81.5	2	126.3	8	375.7§
Nonmalignant Respiratory Disease (460 to 519)	311	79.4§	19	54.7§	15	38.1§
Cirrhosis of the Liver (571)	68	67.0§	5	61.0	6	51.5
All External Causes of Death (E800 to E999)	492	77.1§	23	52.3§	30	41.2§
Motor Vehicle Accidents (E810 to E823)	153	76.3§	7	49.1	9	38.1§
Suicides (E950 to E959)	101	103.8	4	50.0	6	48.0

* Hourly, n = 14,691.
† 25 to 75% salaried, n = 821.
‡ 90 to 100% salaried, n = 2262.
§ Significant at 1% level.
‖ Significant at 5% level.

causes in the 1940 through 1945 stratum.

Three causes were significantly elevated in the pre-1940 stratum: Hodgkin's disease (SMR = 205.2), benign and unspecified neoplasms (SMR = 218.8), and hypertension without heart disease (SMR = 145.9). None of these were significantly elevated in the other period of hire strata. No significantly elevated causes were found in the 1940 to 1945 stratum, whereas kidney cancer was the sole significantly increased cause of death among employees hired in or after 1945 (SMR = 225.1).

The SMR results by pay status for the entire cohort are shown in Table 7. Three strata were formed for the mortality analysis: employment strictly hourly (82% of the total cohort), employment at least 90% salaried (13% of the total cohort), and all other combinations of hourly and salaried employment. The overall SMR for each stratum was significantly less than 100, but the magnitude of the deficit increased with increasing time spent as a salaried

TABLE 8
Lymphatic and Hematopoietic Tissue Cancers by Cell Type (All Men)*

Cell Type	Observed Deaths	Expected Deaths	SMR	95% Confidence Interval
AML (205.0)†	10	15.9	62.7	30.1 to 115.3
CML (205.1)	6	7.1	84.4	31.0 to 183.6
ALL (204.0)	8	3.1	259.6‡	112.1 to 511.5
CLL (204.1)	3	10.0	29.9‡	6.2 to 87.3
NHL (200, 202)	30	42.2	71.0	47.9 to 101.4
MM (203)	19	19.4	98.0	59.0 to 153.0

* AML, acute myeloid leukemia; CML, chronic myeloid leukemia; ALL, acute lymphocytic leukemia; CLL, chronic lymphocytic leukemia; NHL, non-Hodgkin's lymphoma; MM, multiple myeloma.

† Numbers in parentheses are codes for the International Classification of Diseases, Adapted (ICDA), 8th Revision.

‡ $P < 0.05$.

worker. Hourly workers showed significantly elevated SMRs for total malignant neoplasms (SMR = 106.3) and bone cancer (SMR = 228.7). Based on only four deaths, benign/unspecified neoplasms were significantly elevated in the mixed hourly-salaried group (SMR = 433.1). Among salaried workers, significant elevations were found for the benign/unspecified neoplasms (SMR = 365.8) and hypertension without heart disease (SMR = 375.7), but these were based on just a few deaths each: five and eight deaths, respectively.

The set of mortality rates that we used in the OCMAP program does not provide analyses for cell-type specific leukemias, non-Hodgkin's lymphoma, or multiple myeloma. Therefore, separate analyses on these lymphatic and hematopoietic cancers for all men were carried out (Table 8). There were nonsignificant deficits for acute myelogenous leukemia (SMR = 62.7, 95% CI, 30.1 to 115.3), chronic myelogenous leukemia (SMR = 84.4; 95% CI, 31.0 to 183.6), non-Hodgkin's lymphoma (SMR = 71.0; 95% CI, 47.9 to 101.4), and multiple myeloma (SMR = 98.0; 95% CI, 59.0 to 153.0). A significant excess was observed for acute lymphocytic leukemia (SMR = 259.6; 95% CI, 112.1 to 511.5), whereas a significant deficit was observed for chronic lymphocytic leukemia (SMR = 29.9; 95% CI, 6.2 to 87.3).

All of the acute lymphocytic leukemia deaths occurred in white men who were hired before 1955. Two employees were older than 50 years of age when they were hired at the refinery, whereas two other employees worked at the refinery for less than 5 years (.5 and 4, respectively). A trend analysis by length of employment for these deaths was also carried out. Because of the small number of deaths, only three categories were used: <10 years (n = 2 deaths), 10 to 19 years (n = 2), and ≥20 years (n = 4). SMRs in all three categories were elevated, but no individual SMR was significant. A formal test indicated that there was no positive trend by length of employment ($\chi^2_{\text{trend (1 df)}} = .23$, $P = .63$).

Discussion

Comparisons of this update of the Port Arthur refinery cohort to earlier published reports yielded consistent results. The cohort showed a generally more favorable mortality experience than that of the general population. For example, significant mortality deficits were observed for all causes combined, all heart diseases combined, nonmalignant respiratory disease, and external causes.

As in earlier reports about this cohort, bone cancer was significantly elevated for the cohort as a whole. A detailed discussion of the bone cancer excess can be found in two previous reports.[1,7] A review of the actual causes listed on the death certificates indicated that several deaths were the result of tumors of epithelial tissue (carcinomas) rather than sarcomas, ie, they were not tumors of bone tissue (mesenchymal tissue) per se, but rather metastatic tumors from other sites (epithelial tissue). The classification of these cancers reflects the coding rules in the eighth revision of the ICDA, the basis for all cause-of-death coding in former and current mortality analyses. In the ninth revision, the coding rules were modified to prevent metastatic bone tumors from being coded under the rubric of primary bone cancers. Although the coding rules of the eighth revision also applied to the reference rates, and therefore the "bone cancer" finding is statistically valid, from a biological perspective, we do not believe that the metastatic bone cancers should be considered primary cancers. Consequently, this study should not be interpreted as suggesting that mortality from primary bone cancer is related to employment in petroleum refineries. This is further supported by noting there was no exposure-response relationship between bone cancer and length of employment.

Most of the deaths in the significantly elevated benign/unspecified neoplasm category were the result of benign brain tumors. The estimated SMR for benign brain tumors based on Texas death rates was borderline significant (SMR = 173.5; 95% CI, 100.8 to 277.6). Using the US general population, the SMR was reduced to 131.7 (95% CI, 76.5 to 210.7), and was no longer statistically significant. Analysis by length of employment did not reveal any trend. For malignant tumors of the central nervous system, the observed number of deaths was similar to the expected, and the corresponding SMR (117.7) was not significant. The problems associated with diagnostic errors of brain tumors were

discussed in a previous report on the Port Arthur refinery cohort.[5] Errors occur more frequently among inaccessible tumors such as those that occur in the liver, brain, or pancreas. Furthermore, liver and brain are two organs of the body known for their propensity of being metastatic cancer sites.[23,24] In fact, in the original Port Arthur cohort study,[5] six deaths were identified with likely incorrect diagnoses. A potential overreporting of brain tumors in occupational groups as a result of diagnostic sensitivity bias has also been reported in several previous investigations.[25–27]

With respect to the leukemia cell-type analysis, previous analysis of the cohort found no excess in myelogenous leukemia, but reported elevated lymphocytic leukemias in employees who worked for 20 to 29 years at the refinery.[8] However, this earlier analysis did not distinguish between acute and chronic lymphocytic leukemias. A comparable analysis in this update yielded no increase in either acute and chronic lymphocytic leukemias combined (11 observed deaths, 13.0 expected) or acute and chronic myelogenous leukemias combined (16 observed, 23.0 expected). However, a significant increase in acute lymphocytic leukemia (ALL) was found (SMR = 259.6; eight observed deaths, 3.1 expected). Conversely, the SMR for chronic lymphocytic leukemia (CLL) showed a significant deficit (SMR = 29.9; three observed deaths, 10.0 expected).

The ALL excess, coupled with a deficit of CLL, is particularly noteworthy. From a diagnostic perspective, it might have been difficult historically to distinguish between patients with CLL and those with ALL.[28] This difficulty would likely have prevailed during a large portion of the cohort follow-up period. The observations that half (26 of 52) of the leukemia death certificates for white men did not report the cell type (as was the case for three of the four leukemia deaths in nonwhite men), coupled with the fact that combined ALL and CLL death categories yielded an SMR not significantly different from expected (ie, 100), lend credence to the possibility of diagnostic difficulty, and hence, misclassification with respect to recording the cause of death.

Indeed, if even one ALL case was the result of misdiagnosis, the ALL SMR would not have been statistically significant. In this regard, it is noteworthy that one of the ALL death certificates listed the cause of death as "Alymphatic [sic] leukemia". As this is not a generally recognized diagnosis, we could not determine the cell type of this cancer. Nevertheless, we coded it as acute lymphocytic leukemia in our analysis and as such, the statistical significance of the ALL result rests on a questionable diagnosis.

We also examined the work histories for the ALL cases. However, because of the lack of specificity and nonstandardized way that the information was recorded for cohort members during the early time periods covered by the study, no additional insight regarding possible occupational associations could be gleaned from this review.

Potential for exposure to benzene or benzene-containing mixtures exists at every petroleum refinery. Under conditions of high concentration and long duration, benzene is recognized as a human leukemogen. However, acute myelogenous leukemia is the type most strongly linked to benzene exposure. No epidemiologic study has demonstrated an association between exposure to benzene and acute lymphocytic leukemia. Similarly, no other petroleum refinery study has reported an increase of ALL.[29] Based on a meta-analysis of a combined cohort of more than 208,000 petroleum workers in the United Kingdom and the United States, including those at Port Arthur, the ALL SMR was 115.8 (95% CI, 80.2 to 161.8).[29] When the Port Arthur data was removed from the meta-analysis, the ALL SMR became 99. Thus, the finding from the Port Arthur refinery was not consistent with other studies of refinery workers with similar exposures.

The likely spurious nature of the ALL finding in the Port Arthur cohort is further supported by the lack of an exposure-response relationship based on length-of-employment analysis. In addition, with most of the deaths occurring in employees hired before 1950, acute lymphocytic leukemia does not appear to be a problem in more recently hired employees.

The objective of the length of employment analysis was to determine if there was a consistent upward trend in the exposure-response relationship, which we would consider important in our interpretation of potential causality. Hypertension without heart disease and diabetes were the only causes to show positive trends, but in neither case was the trend strictly increasing. Instead, each trend was solely the result of an increase in the longest length-of-employment stratum, whereas no trend was apparent across the other strata. In addition, the period-of-hire analysis showed that the increases in hypertension and diabetes were limited to employees hired before 1945. This suggests that if occupational exposures did contribute to these deaths, the exposure is not affecting employees hired after 1945. Lastly, the increase in hypertension was limited to salaried workers whose potential refinery exposures were likely to have been briefer and less intense than those of hourly workers.

In general, several significant cause-specific mortality deficits, as well as elevations, were noted in individual length-of-employment strata. Apart from the two causes of death discussed above, no consistent pattern was detected for any cause of death. Because of the large number of SMRs calculated for various causes of death, length-of-employment categories, and sex-race subcohorts, some of the SMRs might have been statistically significant as a result of chance. With the large num-

ber of strata, the number of deaths in some of the individual strata might be small, and the corresponding individual SMRs might not be reliable. As such, for length-of-employment analysis, only trends in the data and not individual SMRs were emphasized.

As in the length-of-employment analyses, several individual strata in the interval-since-hire analyses showed significant mortality deficits and elevations. Among causes with significant elevations, trend analyses with respect to length of employment did not indicate the presence of positive trends with the exception of diabetes in nonwhite men. Diabetes is not generally associated with employment in the petroleum-refining industry. For example, we found only a single report of an elevation that is statistically significant[30] (significance calculated by K.P.S).

The interval-since-hire analyses, as well as those based on period of hire and pay status, did not reveal any major new findings. These analyses were also affected by the same issues discussed above, in conjunction with length of employment analysis. For period of hire, the updated results are in agreement with earlier accounts of the cohort[13] regarding differences among employees hired in the 1940 to 1945 period vs other times: women were more likely to be hired, employees tended to work at the refinery for a very short period, and overall, the healthy worker effect was not apparent. Primarily because of the short employment duration, significant elevations occurring only in the subcohort hired in the 1940 to 1945 period should not be given much weight, because for these employees, the opportunity for exposures was much greater outside of the Port Arthur refinery than while they were employed there.

With respect to the period-of-hire analysis, kidney cancer was the only cause of death with a significantly elevated SMR. This occurred in cohort members hired after 1945. Remarkably, ten of the 12 deaths were in persons hired during a very brief interval, 1946 to 1951, and the subpopulation driving the increase consisted of four nonwhite men who worked less than 1 year at the refinery (SMR = 635.8; 95% CI, 173.2 to 1627.9). Kidney cancer has been the focus of considerable scientific research, both in animals and humans, stemming from an initial study that found an excess of kidney tumors in male rats after chronic exposure to wholly vaporized gasoline.[31] Subsequent toxicologic research has been critical of this finding's relevance to humans.[32] Similarly, a recent review of the epidemiologic evidence found that most studies do not support a link between gasoline exposure and kidney cancer.[33] More specifically, several recently completed studies among petroleum refinery and distribution workers exposed to gasoline failed to identify a significantly increased risk for kidney cancer.[34–37] These observations, together with the period of hire and short length of employment among the subpopulation driving the kidney-cancer increase, detract from a causal association between this cancer and employment at the refinery.

Similar to other industrial facilities, asbestos was used at the Port Arthur refinery in the past. Although specific exposure measurements were not available, data from the industry as a whole have indicated that asbestos concentrations at refineries were generally low.[38] In the Port Arthur cohort, no asbestos-related diseases showed statistically significantly elevated SMRs. For example, no asbestosis deaths were reported, and for deaths resulting from causes in the general category of pulmonary fibrosis, the SMR of 35.0 was significantly low. Mortality from lung cancer was not significantly different than expected (SMR = 92.9), nor did it show a trend by duration of employment. The lung-cancer SMR result contrasts other reports of asbestos-exposed workers, which show threefold to 90-fold increases, depending on worker smoking status.[39] Malignant mesothelioma, another asbestos-related disease, did not have a significantly elevated SMR: six deaths were observed, whereas 5.9 were expected (SMR = 101.7). Finally, although three deaths resulting from benign mesothelioma were observed, this disease is a clinicopathologic entity distinct from malignant mesothelioma and is not associated with exposure to asbestos.[40–42] Hypothetically, if these three deaths were misclassified as benign, adding them to the six malignant mesotheliomas would not have resulted in a statistically significant SMR.

It should be pointed out that there were several limitations in the study, most of which are typical of historical cohort mortality studies of industrial populations. First, death certificates for 5% of the deaths identified could not be retrieved. Although these deaths were included in the all-causes-combined analyses, some cause-specific SMRs might have been affected (underestimated) because of these missing death certificates. Second, the vital status of 6.5% of the men and 31.1% of the women in the cohort was unknown. This missing information might have affected some of the results, especially for women in the study. In this regard, the results for women should be viewed cautiously. Third, because it is a mortality study, this investigation inherited the problems associated with death certificates (eg, diagnostic accuracy and comparability of the ICD codes over time). In particular, the use of the eighth revision of the ICDA was problematic in analyzing bone cancer. Fourth, some analyses were potentially affected by the limited availability of reference rates for comparison. For example, for specific lymphatic and hematopoietic cancers, rates for white men were used for all men. Furthermore, certain mortality rates were not available for the entire observation period. Fifth, although the Gulf Port Arthur refinery cohort is probably one of the largest in the petroleum

industry, for some causes, the number of deaths was still relatively small. For these causes, some results might not be statistically stable or reliable. Finally, the interpretation of the results is limited by the absence of quantitative exposure data. Because of this, we relied on indirect measures of exposure: length of employment, period of hire, and pay status. Although this is a common practice in occupational epidemiologic studies, the use of surrogates may result in misclassifying employees with respect to possible exposures which could result in some SMRs being under- or overestimated.[43]

Conclusion

In summary, the results of the updated study demonstrated a favorable mortality experience for the Port Arthur refinery employees as compared with the Texas general population or the US general population. Most causes of death showed either a similar mortality or a statistically significant deficit among the refinery employees when compared with the general population. Only a few causes of death showed statistically significant elevations. Further analyses by length of employment, trends over time, potential misclassification due to nosology rules, and likelihood of exposure given pay status job classifications did not support a conclusion that causes of death with elevated SMRs resulted from employment at the refinery. Moreover, any such causal interpretation would need to be tempered by the possibility that the statistically significant finding is a chance occurrence as a result of the numerous statistical comparisons made in the study.

Acknowledgments

The authors thank Anita Ross, Tom Mach, Diane Petterson, and Odessa Williams for their assistance in performing the cause-of-death quality assurance.

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ARTISTS' PAYCHECKS

Name	1994 Income	1995 Income
Steven Spielberg	$165,000,000	$120,000,000
Oprah Winfrey	72,000,000	74,000,000
Beatles	30,000,000	100,000,000
Rolling Stones	50,000,000	71,000,000
Michael Jackson	22,000,000	45,000,000
Barbra Streisand	52,000,000	11,000,000
Sylvester Stallone	24,000,000	34,000,000
Tom Hanks	16,000,000	36,000,000
Bill Cosby	34,000,000	15,000,000
Andrew Lloyd Webber	24,000,000	24,000,000
David Letterman	15,000,000	14,000,000
John Grisham	16,000,000	13,000,000
Tom Clancy	13,000,000	15,000,000
Robin Williams	10,000,000	15,000,000
Kevin Costner	15,000,000	9,000,000
Demi Moore	9,000,000	12,000,000

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