

Update of a Mortality Study of Workers in Petroleum Refineries

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A large cohort of petroleum refinery workers with long duration of employment, long latency, and relatively young age at hire had its vital status updated through Dec 31, 1980. The standardized mortality ratio (SMR) for all causes was 78. Each nonneoplastic cause had an SMR below 100, including SMRs of 63 for emphysema and for all diseases of the genitourinary system and of 73 for chronic nephritis. The SMR for all cancers was 87. SMRs for specific neoplasms included digestive system, 90; lung, 85; kidney, 68; brain, 89; leukemia, 101; multiple myeloma, 123; unspecified lymphoma, 112; polycythemia vera (four deaths), 455; myelofibrosis (three deaths), 201; and benign and unspecified brain neoplasms, 108. There were nine deaths from mesothelioma; all nine employees had more than 20 years of employment, with an SMR of 241.

In January 1972, Tabershaw-Cooper Associates, Incorporated (TCA), under the sponsorship of the American Petroleum Institute (API), began a retrospective cohort mortality study of workers in a sample of United States petroleum refineries. The original report was widely distributed by API. Because the cohort is not only large but is also one with long latency and duration of exposure with early age at hire, this study is likely to be a particularly valuable addition to the literature. Therefore, the cohort's vital status has been updated, and a detailed analysis was carried out.

Methods

The vital status of the cohort was updated through

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Dec 31, 1980. Data were analyzed by a modified life table program adapted from the one described by Monson¹ and a computer program from the National Institute for Occupational Safety and Health (NIOSH).² For study cohort members lost to follow-up, person-years were accumulated until time of loss. The standardized mortality ratio (SMR) for multiple myeloma (which was not available in either the Monson or NIOSH program) was calculated from data provided by Dr Gary Marsh. SMRs for mesothelioma were calculated from expected numbers generated by age-specific rates for white males for the years 1969 to 1971 from the Third National Cancer Survey (M. Myers, personal communication, 1984) and annual age-specific rates for males from the SEER Program for the years 1973 to 1978.³

In all the above analyses, black males were analyzed in comparison with the mortality experience of nonwhite males. All other study cohort members had their mortality experience compared with that of white males, and the results were combined. Based on the distribution by plant of those cohort members with known race, we estimate that 99.9% of those whose mortality experience was compared with that of white males were white.

TCA collected 20,169 individual records for this study. Of these, 178 (0.9%) were eliminated from the analysis for the following reasons:

1. Seventy-nine workers from one refinery were eliminated because the records for men who had quit or were discharged were kept for only 1 year unless the employee had died on the job.
2. Forty-one had worked less than 1 year between 1962 and 1971.
3. One was female.
4. Fifty-seven were duplicate records, including ten of employees who qualified in more than one participating refinery.

With the elimination of these records, the total cohort size for follow-up and analysis became 19,991.

Results

Through Dec 31, 1980, 15,935 of the cohort were known to be alive, 3,349 were known to be deceased, and 707 (3.5%) were of unknown vital status. Of the cohort, 51.3% were hired between 1940 and 1954, and 17.2% were hired before 1940. As of this update, more than two-thirds of the cohort had been employed in participating refineries for more than 20 years. The mean age at hire for the cohort was 26.2.

The Table shows the causes of death from the Monson program analysis, the observed and expected deaths, the SMRs, and the 95% confidence intervals. Information on cause of death was not available for 80 deaths (2.4% of the total), and SMRs were not adjusted for these unknown deaths. If they were, the SMRs would be between 2% and 3% higher for each cause.

For all causes, the number of observed deaths is less than four-fifths of the number expected. The SMRs are even lower for many specific causes, including cancer of the kidney, emphysema, and diseases of the genitourinary system. In addition, because of the large numbers involved, some SMRs are significantly low even though they are close to 100, including all malignant neoplasms and lung cancer.

Of the 30 deaths from cancer of other lymphatic tissue, 16 were from multiple myeloma. The number of expected deaths was 12.99, giving an SMR of 123 for this cause and a 95% confidence interval of 70 to 200. Of the 14 other deaths from this cause, four were from polycythemia vera, and the other ten were from other neoplasms of lymphoid tissue (Code 208, International Classification of Diseases, Eighth Revision).

There was one benign brain neoplasm, with 1.87 expected, for an SMR of 55. For the unspecified brain neoplasms, there were seven deaths, with 5.51 expected, for an SMR of 127 and a 95% confidence interval of 51 to 269.

Nine mesotheliomas were found, all with more than 20 years duration and latency. In addition, we know of one other employee who was alive at the end of the study but who died in 1983 and whose death certificate listed mesothelioma as the cause of death. That employee also had a long duration of employment and a long interval between start of employment and death. Of the nine deaths from mesothelioma by the closing date of the study, six clearly were indicated to be pleural mesothelioma on the death certificate. For the three others, it is not clear whether they were pleural or peritoneal. Of the occupations recorded on the death certificates, three were machinists, two were welders, and one each was an insulator, maintenance supervisor, "Utility Division," and pipe fitter. One death certificate listed asbestosis as a secondary cause. The expected number of mesotheliomas in the study cohort was 3.73 for an SMR of 241, with a 95% confidence interval of 110 to 458.

Discussion

The cohort is at lower risk for all deaths and for many

TABLE
Observed and Expected Deaths and Standardized Mortality Ratios (SMRs) by Cause, for Male Employees of Petroleum Refineries Through Dec 31, 1980*

Causes	Observed Deaths	Expected Deaths	SMR	95% Confidence Interval
All causes	3,349	4,280.35	78	76-81
Infective and parasitic disease	15	38.07	39	22-65
Tuberculosis	3	18.02	17	3-49
Malignant neoplasms	793	915.59	87	81-93
Cancer of buccal cavity and pharynx	18	30.37	59	35-94
Cancer of digestive organs and peritoneum	223	246.91	90	79-103
Cancer of esophagus	20	26.51	75	46-117
Cancer of stomach	43	44.06	98	71-131
Cancer of large intestine	73	77.76	94	74-118
Cancer of rectum	27	25.78	105	69-152
Cancer of liver	13	16.04	81	43-139
Cancer of pancreas	44	51.25	86	62-115
Cancer of respiratory system	278	335.19	83	73-93
Cancer of larynx	8	14.63	55	24-108
Cancer of lung	270	317.72	85	75-96
Cancer of bone	4	3.85	104	28-266
Cancer of skin	15	14.05	107	60-176
Cancer of prostate	60	58.81	102	78-131
Cancer of testis	4	4.08	98	26-251
Cancer of bladder	15	25.48	59	33-97
Cancer of kidney	15	22.09	68	38-112
Cancer of eye	0	0.72	0	0-509
Cancer of brain and other parts of nervous system	22	24.63	89	56-135
Cancer of thyroid	2	1.64	122	14-440
Neoplasms of lymphatic and hematopoietic tissue	88	82.50	107	86-131
Lymphosarcoma and reticulum cell sarcoma	16	17.78	90	51-146
Hodgkin's disease	7	8.73	80	32-165
Leukemia	32	31.68	101	69-143
Cancer of other lymphatic tissue	30	22.82	131	89-188
Cancer of other and unspecified sites	50	65.30	77	57-101
Benign neoplasms	14	10.54	133	79-223
Endocrine, nutritional, and metabolic diseases	45	76.19	59	43-79
Diabetes mellitus	37	64.58	57	40-79
Diseases of blood and blood-forming organs	8	8.93	90	39-177
Mental disorders	3	27.06	11	2-32
Diseases of nervous system and sense organs	19	34.20	56	33-87
Diseases of the circulatory system	1,727	2,185.31	79	75-83
Chronic rheumatic heart disease	26	34.79	75	49-110
Ischemic heart disease	1,267	1,575.45	80	76-85
Cerebrovascular disease	188	287.60	65	56-75
Diseases of respiratory system	167	262.91	64	54-74
Pneumonia	45	88.94	51	37-68
Emphysema	46	72.91	63	46-84
Asthma	5	6.32	79	26-185
Diseases of digestive system	121	211.83	57	47-68
Peptic ulcer	14	24.71	57	31-95
Cirrhosis of liver	65	119.90	54	42-69

TABLE—Continued

Causes	Observed Deaths	Expected Deaths	SMR	95% Confidence Interval
Diseases of genitourinary system	33	52.52	63	43-88
Chronic nephritis	13	17.93	73	39-124
Diseases of the skin and subcutaneous tissue	3	3.15	95	19-278
Diseases of the musculoskeletal system and connective tissue	3	7.54	40	8-116
Symptoms and ill-defined conditions	54	63.78	85	64-110
Accidents, poisonings, and violence	260	375.52	69	61-78
All accidents	164	237.98	68	59-80
Motor vehicle accidents	77	106.32	72	57-91
Suicide	57	81.95	70	53-90
All other causes	12	19.14	63	32-110
Unknown	80			

* No. of workers: 19,991. No. of person-years: 297,591.9.

specific causes of death. The 96.5% follow-up rate compares favorably with follow-up rates usually achieved in retrospective cohort mortality studies and fewer than 2.5% of the death certificates were not obtained.

Part of the explanation for these low SMRs appears to be the well-known healthy worker effect. Anecdotally, people familiar with petroleum refineries have noted that heavy smokers are not likely to work there because of the smoking restrictions for safety purposes that are imposed at work. In combination with the usual healthy worker effect, the anecdotally noted low smoking prevalence among refinery workers may explain these findings.

The accuracy of the diagnoses and the appropriateness of the comparison data could have affected the results for mesothelioma. The probable net result is that the expected number of deaths from this cause is slightly overestimated, which means that the SMR is, if anything, underestimated.

There were nine observed deaths and 7.93 expected deaths from ICD Code 202.2 in the Eighth Revision (other primary malignant neoplasms of lymphoid tissue) for an SMR of 113 with a 95% confidence interval of 52 to 216. For the remainder of Code 202 (other than

202.2) in the Eighth Revision (and for Codes 202 and 205 in the Seventh Revision, which equate to Code 202 in the Eighth Revision) there were one observed death and 1.03 expected deaths, for an SMR of 97. For polycythemia vera there were four observed deaths and 0.88 expected deaths from this cause for an SMR of 455, and 95% confidence interval of 120 to 1,164.

The 88 observed deaths from neoplasms of lymphatic and hematopoietic tissue are three more than the observed deaths from each of the components (lymphosarcoma and reticulum cell sarcoma, Hodgkin's disease, leukemia, and cancer of other lymphatic tissue). The difference is the three deaths from myelofibrosis. The expected number of deaths was 1.49, which gives an SMR for that cause of 201 with a 95% confidence interval of 41 to 588.

It would appear that the concern about neoplasms of the lymphatic and hematopoietic system arises primarily from polycythemia vera, and perhaps from myelofibrosis. There is some question as to whether these are really neoplasms, and the Seventh Revision places them both under diseases of the blood and blood-forming organs. However, the numbers are too small for polycythemia vera and myelofibrosis to warrant further investigation at present.

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TABLE A7

Percent Disagreement for Sub-Cohort Classification

<u>Sub-Cohorts</u>	<u>Intra</u> <u>(341 pairs)</u>	<u>Inter</u> <u>(182 pairs)</u>
Exposed	2.1%	3.3%
Not Exposed	2.3%	4.4%
Not at Beaumont, or Location Code Missing	3.8%	4.9%

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