A prospective study in the Australian petroleum industry. I Mortality

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Abstract

This paper reports the mortality experience of employees of the Australian petroleum industry from 1981 to 1989. Two surveys by personal interview incorporated more than 15 000 employees representing 92% of the eligible population. Subjects were included in the analysis after completing five years of service in the industry. At the time of this report the cohort does not include sufficiently large numbers of women for useful analysis; results presented are restricted to men. By 31 December 1989, 76 529 person-years of observation had accumulated for male mortality with 241 deaths. The standardised mortality ratio (SMR) analysis showed a favourable mortality experience for most causes with overall cancer rates slightly lower than those of the national population. Whereas deficits were seen in some cancer sites, notably lung cancers (SMR 0.5, 95% confidence interval (95% CI) 0.3-0.8), mortality for lymphohaematopoietic cancers, notably leukaemia (SMR 1.6, 95% CI 0.6-3.4) suggested increased risk. The SMR for cancers of the pleura was 3.9 (95% CI 0.8-11). Two of the three cases seen had previous employment, however, in industries with likely exposure to asbestos.

Although the petroleum industry has been the subject of many epidemiological investigations over the past 20 years, the relation between occupational exposure to hydrocarbons and the risk of cancer remains far from clear. Several reviews have been published in recent years;¹⁻⁴ an increased risk of cancer at varying sites has been reported but no

consistent pattern has emerged. With the exception of the programme known as Health Watch, which is the subject of this paper, and one other with a prospective design in the United States⁵ the major studies have examined historical cohorts with mortality as the endpoint; nested case-control studies were established within some of these. Most reports have come from the United States, but work has also been carried out in Canada, the United Kingdom, and Italy, and has included multicompany enterprises as well as single company and worksite studies.

Oil exploration in Australia began in the 1890s, some 40 years after the first discovery in the United States. In the first decade of the twentieth century, British and American companies opened branch offices in Australia and imports of motor spirit and lubricants began. Local refineries were built from 1910 onwards and nationwide distribution networks were set up for both motor gasoline and aviation fuel. After the second world war a boom in population and secondary industry occurred that increased demand and resulted in the development of significant local refining capacity with major refineries in three states coming on stream during the 1950s. In a country characterised by large sparsely populated areas and high living standards the movement of goods and people demands high per capita petroleum consumption, but from the 1970s local production of lighter qualities of crude oil and of natural gas made Australia an overall net energy exporter. The national industry encompasses all phases of production, refining, manufacture, and distribution, only relying on overseas sources for heavy crude oil and petroleum products, mainly fuel oil.

In 1980 the Australian Institute of Petroleum (AIP) contracted the University of Melbourne to establish a concurrent prospective study of employees in the industry to monitor the Australian experience. The introduction of population based cancer registries in all Australian states has permitted the study reported here to take a two pronged approach, examining both mortality and incidence outcomes for specific cancers. This paper considers mortality in the cohort for the years 1981-9. Results for incidence are presented in the accompanying paper which forms part II of the report on the current state of the cohort.⁶

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Methods

The cohort was established by baseline surveys of personal interviews in 1981–3 and in 1986–7. All employees of major petroleum companies operating in Australia and working in refineries, storage and distribution terminals, production facilities, and airports were eligible; excluded were those working at head offices or at sites with fewer than 10 employees. The response rate to the survey was 92%, resulting in an initial population of 10 979 men and 626 women; a full description of the methodology has been presented elsewhere.⁷ The survey was repeated in 1986–7 enabling employees hired subsequent to the first survey to enter the study. Analyses in this paper are confined to men because the women in the cohort have not accumulated sufficient person-years for useful analysis.

For logistic reasons and for considerations of latency employees have not been included in the analysis until they have completed five years of service. Once the minimum period of employment has been achieved, employees are followed up yearly, whether they are still employed or subsequently leave the industry through resignation, retirement, or redundancy.

Personal interviews enabled us to gather detailed and accurate descriptions of work areas and tasks as well as information on potential confounding variables such as tobacco smoking. Jobs were coded according to the system developed for the American Petroleum Institute (API).⁸ At selected worksites surveyed in the two most populous states of Australia a 10% sample of self described job titles was validated against supervisors' descriptions; no significant discrepancies were found. Age specific smoking prevalences were found to be close to those determined in the Australian National Heart Foundation population surveys.⁹

Follow up of the population is maintained through company records for those still employed and by yearly mail contact for those who have left the industry. The names of those lost to contact (3%) are searched for every second year against all state death registers, giving national coverage. Death certificates

are obtained for all deceased subjects and when cancer appears on the certificate further information is sought from the certifying doctor.

Standardised mortality ratios (SMRs) have been calculated using the Australian national mortality statistics as reference; the standard rates used for deaths to the end of 1985 are the average rates across 1981–5, and those used for deaths from 1986 to 1989 are the average rates for 1986–7. To ensure comparability with national rates death certificates are sent to the Australian Bureau of Statistics for coding according to the ninth revision of the international classification of diseases (ICD 9). The usual Poisson assumption was made for the observed number of deaths, leading to "exact" 95% confidence intervals (95% CIs) for the SMRs.¹⁰

Within what appears from available workplace data to be an overall low exposure situation, job codes have been ranked by a committee of occupational hygienists of the Australian petroleum industry, producing seven categories representing increasing potential for exposure to total hydrocarbons. Comparisons of all cause mortality and cancer mortality between exposure levels were made by computing relative mortality rates (RMRs), adjusted for age and smoking habit, against "office" as the baseline of least exposed category. Statistical estimates of trend have been made. These analyses use log linear models, again with a Poisson assumption.¹¹ The calculations were done using GLIM.¹²

Results

MORTALITY BY CAUSE

This paper reports the mortality state of the cohort at 31 December 1989 when 72 871 person-years were available for analysis. Table 1 shows that 241 deaths had occurred (SMR 0.63, 95% CI 0.55–0.71); of these, 90 deaths were coded with the underlying cause as cancer (SMR 0.8, 95% CI 0.6–1.0). For the other major cause of death, ischaemic heart disease, a significant deficit was found (SMR 0.7, 95% CI 0.5–0.9). Significant deficits were also found for respiratory disease, for stroke, for accidents and violence, and for causes not otherwise classified.

Table 1 Mortality by major cause: men

Cause	ICD 9	Obs	Exp	SMR (95% CI)
Cancer	140–208	90	115.1	0.8 (0.6–1.0)
Ischaemic heart disease	410–414	76	111.4	0.7 (0.5–0.9)
Stroke	430–438	7	18.7	0.4 (0.2–0.8)
Respiratory disease	460–519	11	19.6	0.6 (0.3–1.0)
Other diseases of the digestive system	570–579	10	15.0	0.7 (0.3–1.2)
Accidents and violence	800–999	27	52.2	0.5 (0.3–0.8)
All other causes		20	47.2	0.4 (0.3–0.7)
All causes		241	384.1	0.63 (0.55–0.71)

Obs = No of observed deaths; Exp = Expected No of deaths.
Test for constant SMR, $p = 0.06$.

Table 2 Mortality for cancer sites: men

Malignant neoplasm of:	ICD 9	Obs	Exp	SMR (95% CI)
Stomach	151	7	5.7	1.2 (0.5-2.5)
Colon	153	11	11.3	1.0 (0.5-1.7)
Rectum	154	4	4.7	0.8 (0.2-2.2)
Pancreas	157	4	5.1	0.8 (0.2-2.0)
Larynx	161	2	2.1	1.0 (0.1-3.5)
Lung	162	16	34.3	0.5 (0.3-0.8)
Pleura	163	3	0.8	3.9 (0.8-11)
Connective tissue	171	2	0.9	2.3 (0.3-8.4)
Melanoma	172	6	5.0	1.2 (0.4-2.6)
Prostate	185	2	4.0	0.5 (0.1-1.8)
Kidney	189	2	3.0	0.7 (0.1-2.4)
Brain	191	6	4.8	1.3 (0.5-2.7)
Unspecified	199	3	5.8	0.5 (0.1-1.5)
Non-Hodgkin's lymphoma	200 and 202	5	4.3	1.2 (0.4-2.7)
Multiple myeloma	203	3	1.6	1.9 (0.4-5.7)
Leukaemia	204-208	6	3.9	1.6 (0.6-3.4)
Lymphoid	204	1	1.1	0.9 (0.0-5.2)
Myeloid	205	4	2.4	1.7 (0.5-4.2)
Other leukaemia	206-208	1	0.4	2.9 (0.1-16)
Other sites		8	18.1	
All sites		90	115.1	0.8 (0.6-1.0)

SITE SPECIFIC CANCER MORTALITY

Analysis of mortality from cancer by main anatomical site (table 2) showed a deficit for lung cancers (SMR 0.5, 95% CI 0.3-0.8). The SMR for cancers of the pleura was 3.9 (95% CI 0.8-11.0) based on three cases.

Deaths ascribed to cancer of the lymphatic and haematopoietic tissue suggested raised risk, with raised SMRs for non-Hodgkin's lymphoma (SMR 1.2), multiple myeloma (SMR 1.9), and leukaemia (SMR 1.6). In each of these conditions the 95% CIs included unity. The SMR for melanoma was 1.2 (95% CI 0.4-2.6). All other SMRs were in the range 0.7 to 1.3, with the exception of connective tissue (SMR = 2.3, two cases).

INTERNAL COMPARISONS OF OCCUPATIONAL EXPOSURES

After adjustment for age and smoking, little relation was found between all cause mortality and potential exposure to hydrocarbons as measured by exposure categories (test for trend, $p = 0.7$). A slight trend was present for increasing mortality with earlier employment (table 3) but this did not reach significance ($p = 0.3$).

TOBACCO SMOKING

Relative mortalities, adjusted for age, were found to increase in a stepwise fashion with increased tobacco smoking; the RMR for those smoking at least 30 cigarettes a day was 2.2 (95% CI 1.5-3.54). Ex-smokers with greater than five years of abstinence were found to carry no greater risk than those who had never smoked. Table 4 shows the all cause mortality by smoking category relative to never smoked and adjusted for age.

Discussion

The transformation of crude oil into marketable

products necessitates many processes, mostly enclosed, but all carrying potential exposure to petroleum hydrocarbons. The carcinogenic potential of these chemicals has been recognised for many years and has been fully reviewed by Bingham *et al.*¹³ Currently the International Agency for Research on Cancer (IARC) recognises soots, tars and mineral oils, and benzene as being carcinogenic to man. Thus work in the petroleum industry could expose employees to added risk of cancer and this theoretical hazard has stimulated numerous epidemiological studies, beginning with Gafaer and Sitgreave's work in 1940.¹⁴ From what is generally known of the carcinogenic potential of hydrocarbons it would be expected that if any cancer hazard was present in the industry it would manifest in the skin, lungs, or lymphohaematopoietic systems.

In the study described here a deficit of lung cancer is apparent. With the exception of a recent report by Bertazzi *et al.*,¹⁵ this finding has been reasonably consistent across the epidemiological studies carried out in the industry.¹⁻⁴ Confounding by tobacco smoking could have concealed a true excess as smoking is forbidden in many areas of the workplace. This has been suggested as an explanation by Harrington,¹ but can be rejected in this cohort because smoking data are available for each member and smoking rates do not differ appreciably from

Table 3 All cause mortality by period of first employment adjusted for age and calendar period of follow up: men

Period of first employment	Deaths	RM (95% CI)
1975-84	28	1.0
1965-74	73	1.3 (0.8-2.1)
1955-64	89	1.7 (1.0-2.8)
-1954	51	1.4 (0.8-2.5)

Test for trend $p = 0.3$.

Table 4 All cause mortality by smoking category: men adjusted for age

Category	Deaths	RM (95% CI)
Never	55	1.0
1-19 cigarettes/day	15	1.2 (0.7-2.1)
20-29 cigarettes/day	57	2.0 (1.4-2.9)
30+ cigarettes/day	38	2.2 (1.5-3.4)
Cigar, pipe, mixed	18	1.7 (1.0-2.9)
Ex-smoker (> five years)	39	0.9 (0.6-1.4)
Ex-smoker (< five years)	19	1.2 (0.7-2.1)

Test for trend among current smokers, $p < 0.001$.

those reported in the Australian general population used as a referent group. The consistent reporting of low rates of respiratory cancer in the petroleum industry, combined with the results of this study, which has found a significant deficit in mortality from lung cancer and a significant deficit in mortality from other respiratory diseases, is puzzling and merits further investigation.

Nevertheless, tobacco smoking is firmly established as an exposure associated with premature death and this is supported by the increase in mortality with smoking category found in the Health Watch cohort.

The three cases of cancer of the pleura contributing to a significantly raised SMR were all mesotheliomas. Two of these cases, however, had previous employment as fitters in industries with likely exposure to asbestos; one had worked in the housing industry in the 1960s, and the other in a shipyard in the 1940s.

The only skin cancer available for mortality analysis is melanoma, as squamous and basal cell carcinomas do not generally appear on death certificates. In this study six deaths were observed with melanoma as the underlying cause, compared with four expected. Among mortality studies in the industry, only that of Rushton and Alderson¹⁶ reported an excess of deaths attributable to melanoma, but ecological work has suggested higher death rates from melanoma in United States counties with petroleum and chemical industries.¹⁷ The accumulation of further person-years should help to elucidate the true picture in the Australian industry.

Cancer of the lymphohaematopoietic system, particularly leukaemia, is of concern in the petroleum industry if for no other reason than the ubiquitous presence of benzene, albeit in low concentrations. The mortality results of this study offer no cause for complacency, but contribute little that is new to the understanding of the problem. In the accompanying paper on incidence of cancer it has been possible to look at the situation in more depth.

In general, male workers in the Australian petroleum industry have been shown to be at lower risk of premature death than members of the general Australian population. This is to be expected in view of the well known healthy worker effect.¹⁸ Whereas this effect may contribute to the deficits in deaths from

ischaemic heart disease, stroke and respiratory disease, the considerable deficit in deaths from accidents and violence is more difficult to interpret and merits further investigation.

An overall low mortality can conceal the presence of excess risk from diseases that are not common; this could be the case with lymphohaematopoietic cancers in the petroleum industry and the situation should become clearer with time.

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