Original Research

Cancer mortality in metal workers

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Age-standardized proportional mortality ratios (PMRs) were calculated for 10 036 metal workers in British Columbia with the use of information on cause of death and occupation recorded in death registrations from 1950 to 1978. Metal workers were found to have a significantly increased risk of death from lung cancer (PMR = 134). In addition, certain occupational groups of metal workers were found, for the first time, to be at increased risk of death from other types of cancer; these included leukemia (PMR = 356) and cancer of the rectum (PMR = 248) in metal mill workers, Hodgkin's disease in welders (PMR = 242) and multiple myeloma in machinists (PMR = 209).

Les taux de mortalité proportionnels (TMP) corrigés pour l'âge de 10 036 ouvriers métallurgistes de Colombie Britannique ont été calculés à partir de l'information sur la cause de décès et le métier inscrits à la liste des décès pour la période de 1950 à 1978. Une augmentation significative du risque de décès par cancer du poumon a été trouvée chez les ouvriers métallurgistes (TMP = 134). De plus, pour la première fois on a trouvé une augmentation du risque de décès par d'autres types de cancer chez certains corps de métier appartenant au groupe des ouvriers métallurgistes; ainsi, on a noté une augmentation des leucémies (TMP = 356) et des cancers du rectum (TMP = 248) chez les ouvriers des aciéries, de la maladie de Hodgkin chez les soudeurs (TMP = 242) et des myélomes multiples chez les machinistes (TMP = 209).

Several recent reports have indicated that metal workers in Great Britain and the United States may be at increased risk for certain cancers, including tumours of the lung, bladder, larynx and esophagus.[1-3] In Canada relatively few studies have investigated job-related risks of cancer. In an attempt to delineate risks for major occupational groups in British Columbia, including metal workers, mortality data collected over the period 1950–78 were analysed.

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Methods

Information on all deaths occurring in British Columbia from 1950 through 1978 was obtained from the provincial Division of Vital Statistics. Information was obtained on a total of 457 083 deaths. After eliminating records of deaths in individuals under the age of 20 years as well as a small number of records with invalid information on sex, occupation or cause of death, records remained for the deaths of 165 913 women and 254 901 men. Of the men, 10 036 were metal workers; only 7 women were recorded as metal workers, and they were excluded from this analysis.

Over the 29-year period the underlying cause of death was coded for the death registrations by nosologists at the Division of Vital Statistics according to the sixth, seventh and eighth revisions of the "International Classification of Diseases";[4-6] for this study we reconciled all the codes to the format used in the seventh revision. Two different occupational codes were used between 1950 and 1978; we reconciled the earlier code to the format used in the 1961 Canadian "Occupational Classification Manual".[7]

Age-standardized proportional mortality ratios (PMRs) were calculated for deaths in men aged 20 years and over by the method of Monson,[8] and the significance of the PMRs was assessed by comparison with the Poisson distribution.[9] A total of 216 occupations were analysed according to 158 causes of death.

Results

In several of the categories of metal workers there were relatively few deaths, primarily because of the lack of industries in British Columbia employing such individuals. These categories were metal inspectors and supervisors (108 deaths), tool and die makers (98), metal-working machine operators (64), riveters (36), polishers and buffers (15), coremakers (7), metal heat treaters (6) and rolling mill operators (1). PMR calculations for each of these groups showed no significantly increased or reduced risks of death from any cause because of the small numbers of deaths available for analysis. These 335 deaths are included among the 10 036 deaths for all metal workers in Table I. Five larger groups — forgemen (1031 deaths), metal furnace workers (613), filers and grinders (296), iron moulders (225) and metal workers not elsewhere classified (299)

— showed no significantly raised or lowered risks of death from cancer. No separate information is provided for these groups, but the deaths are also included in Table I.

All metal workers

Metal workers in British Columbia demonstrated increased risks of death from a number of cancers, the most important of which was cancer of the lung (PMR = 134). The risk of death from pleural cavity tumours was also high (PMR = 329), but six of the seven deaths were in plumbers and probably reflect hazards associated with that occupation. The risk of death from stomach cancer was increased (PMR = 111), but not significantly so. The risks of death from cancer of the colon (PMR = 91) and cancer of the rectum (PMR = 109) appeared to be as expected for the whole group. The risks of death from Hodgkin's disease (PMR = 124), non-Hodgkin's lymphomas (PMR = 82) and leukemia (PMR = 95) were neither significantly increased nor significantly decreased. Other types of cancer accounted for 666 deaths in metal workers; the PMRs for these cancers were as expected. Metal workers were at significantly increased risk of death from all cancers combined (PMR = 110). The risk of other major causes of death in this group, including heart disease (PMR = 99) and cerebral hemorrhage (PMR = 102), were as expected. The risk of all accidents combined (PMR = 94) was as expected and should not have caused distortions of the PMRs for individual types of cancer.

Specific occupational groups of metal workers

Table II gives PMRs for the individual types of cancer associated with significantly increased risks of death in specific occupational groups of metal workers. The values for other types of cancer within each occupational group were as expected. Lung cancer was the principal cancer associated with a significantly increased risk of death in the six groups, with metal mill workers being at greatest risk (PMR = 168). In addition, metal mill workers had elevated risks of death from leukemia (PMR = 356) and rectal cancer (PMR = 248), machinists had an increased risk of death from multiple myeloma (PMR = 209), and welders showed higher than expected numbers of deaths from Hodgkin's disease (PMR = 242). The last two groups demonstrated an increased risk of death from all cancers combined. In addition to lung cancer, pleural cavity tumours (PMR = 1441) were a more frequent cause of death than expected in plumbers, and the risk of death from all cancers combined was significantly increased in this occupational group.

Discussion

Mortality studies based on information from death certificates are subject to a number of shortcomings. First, cause-of-death data are much less precise than clinical records. Moriyama and associates[10] analysed available clinical data on deceased individuals and found that only 80% of the death certificates recorded the most probable cause of death. However, cancer fared better than other causes of death in terms of accuracy, with over 85% of the assigned causes being rated as the most probable cause of death. Thus, cancer information on death registrations appears to be relatively reliable. Coding of the cause of death as recorded by the physician is probably better in British Columbia than in most other places as there is a query system to clear up ambiguities before the nosologist assigns the code. There will still be diagnostic and coding errors, but these should be random and should affect each occupational group uniformly. There is no reason to believe that errors specific to any single group biased

Table I—Risks of death among metal workers in British Columbia, 1950–78

ICD-7 no.*	Cause of death	No. of deaths	Proportional mortality ratio (PMR)	Significance level†	95% confidence limits
151	Stomach cancer	228	111	NS	97, 127
153	Colon cancer	146	91	NS	77, 108
154	Rectal cancer	106	109	NS	90, 133
162.0, 162.1, 162.8	Lung cancer	641	134	< 0.001	123, 145
162.2	Pleural cavity tumours	7	329	0.01	132, 679
181.0, 181.8	Bladder cancer	68	101	NS	79, 128
200, 202	Non-Hodgkin's lymphoma	39	82	NS	59, 112
201	Hodgkin's disease	26	124	NS	81, 182
203	Multiple myeloma	33	128	NS	91, 181
204	Leukemia	68	95	NS	75, 121
140–205, 294	All cancers	2 028	110	< 0.001	105, 116
420–422	Arteriosclerosis and degenerative heart disease	3 605	99	NS	96, 103
330–334	Cerebral hemorrhage	902	102	NS	95, 110
E800–E936	All accidents	866	94	NS	87, 101
001–999	All deaths	10 036	–	–	–

*Code used in seventh revision of "International Classification of Diseases".[5]
†Level of significance of the increase or decrease in the risk of death from each cause.

our analysis. In addition, random errors in medical or occupational information and random coding mistakes should decrease the strength of disease–occupation relations, thus lowering the probability of false associations.

There has been some concern about the accuracy of occupational information recorded on death certificates; however, Petersen and Milham[11] found that occupation as reported on the death certificate was correct in 75% of cancer deaths and closely related to the actual occupation in another 10% according to data from interviews with next of kin.

Use of the PMR in occupational studies has disadvantages and advantages. The major disadvantage is that the PMR gives no information on the overall force of mortality within an occupational group.[2] Since the overall PMR for each group must equal 100, a markedly high PMR for a common cause of death, such as heart disease, will have the effect of lowering the PMR for other causes of death. However, PMRs for the major causes of death (arteriosclerosis and degenerative heart disease, cerebral hemorrhage and accidents) appear to be as expected, with values close to 100. Thus, individual cancer PMRs for metal workers should not be affected. On the other hand, use of the PMR avoids some of the disadvantages of the most common comparative mortality measure — the standardized mortality ratio (SMR). The PMR, unlike the SMR, does not require information on either the population at risk or the number of years of follow-up for the group at risk.[12] In addition, the PMR avoids the "healthy worker effect", which is produced when mortality in working groups is compared with mortality in the general population.[8] For most relatively rare causes of death, such as malignant neoplasms, the age-standardized PMR as used in this study is a good approximation of the SMR.[13]

In a study in which large numbers of summary measures of risk are calculated, some disease–occupation associations may appear strictly by chance. It will be important, therefore, to follow up our findings with more detailed studies.

A further difficulty arising in death certificate studies is that none of the factors that might confound the associations can be controlled for. Perhaps, because of the significant excess of lung cancer in the group, the major confounder for this study of metal workers was smoking. It appears that more metal workers smoke than do workers in clerical, administrative and professional occupations;[14] however, a recent Japanese study demonstrated an increased risk of lung cancer in both smoking and nonsmoking metal workers when they were compared with respective smoking and nonsmoking workers from other occupational groups.[15] In addition, a study of steel workers in the United States showed an increased risk of lung cancer in long-term workers even after controlling for smoking.[16] It seems unlikely that differences in cigarette smoking would completely account for the excess mortality from lung cancer in our study.

As well as lung cancer, other types of cancer caused greater than expected numbers of deaths in specific occupational groups of metal workers.

Metal mill workers, including aluminum pot-room workers, are involved in casting and forming operations for metals such as brass, lead and zinc. The excess of deaths from lung cancer found in this group in our study is similar to that found in other studies of aluminum workers exposed to polycyclic aromatic hydrocarbons.[2,17] The finding of an increased risk of death from leukemia

Table II—Groups of metal workers in British Columbia with significantly increased risks of death from cancer, 1950–78

Occupational group	Cause of death	No. of deaths	PMR	Significance level	95% confidence limits
Metal mill workers	Rectal cancer	8	248	0.04	106, 489
	Lung cancer	28	168	0.01	111, 243
	Leukemia	9	356	0.003	162, 675
	All cancers	73	117	NS	92, 147
	All deaths	342	–	–	–
Boiler makers and structural iron workers	Lung cancer	86	157	0.001	127, 194
	All cancers	246	117	0.01	103, 133
	All deaths	1156	–	–	–
Sheet metal workers	Lung cancer	40	138	0.04	101, 188
	All cancers	126	115	NS	96, 137
	All deaths	605	–	–	–
Machinists	Lung cancer	128	122	0.03	102, 145
	Multiple myeloma	12	209	0.03	108, 366
	All cancers	450	110	0.05	100, 121
	All deaths	2220	–	–	–
Welders	Lung cancer	74	145	0.001	115, 183
	Hodgkin's disease	9	242	0.03	110, 460
	All cancers	207	114	0.05	99, 132
	All deaths	1002	–	–	–
Plumbers	Lung cancer	137	144	0.001	121, 171
	Pleural cavity tumours	6	1441	0.001	528, 3137
	All cancers	421	118	0.009	106, 130
	All deaths	1912	–	–	–

in the British Columbia data is new. The increased risk of death from rectal cancer in metal mill workers in British Columbia is also a new finding and will require confirmation in other studies.

The structure of the occupational codes used in this study made it impossible to separate boiler makers from structural iron workers. Iron workers are involved in a number of operations, including erection of steel building frames and fabrication of storage tanks and boilers. Increased risks of death from lung cancer similar to those found in the structural iron workers in our study have been seen in data from the United States and Great Britain.[1-3]

Sheet metal workers fabricate, fit and assemble components for the manufacture of metal ducts, hoods, air-conditioning heat exchangers and many other products. Our finding of an increased risk of death from lung cancer in this group confirms previously observed mortality patterns in Washington State.[18]

Machinists set up and operate lathes, millers, shapers and planers to produce precision parts, usually from hard alloys. These men are exposed to cutting oils and fluids, some of which have been shown to be carcinogenic in mice.[19] Studies in England have shown a higher frequency of skin cancers among machine tool operators exposed to mineral oil lubricants.[20] The most recent data from the United States, however, have indicated no excess risk of lung cancer in machinists.[21] Our finding of an excess risk of death from both lung cancer and multiple myeloma in machinists in British Columbia indicates a need for further study of this group.

An increased risk of death from lung cancer in welders, as we saw in British Columbia, has been reported from the United States and Great Britain.[2,3] In addition, experimental investigation has shown the presence of metal particles in welders' lungs[22] and in the lungs of animals exposed to welding fumes.[23] The higher risk of Hodgkin's disease and multiple myeloma in welders in British Columbia is a new finding and will require confirmation in more detailed studies.

Until fairly recently plumbers have been exposed to a variety of metals, including copper, lead and galvanized iron. In addition, flame cutting, brazing and soldering of pipe joints has exposed them to a variety of fumes. The increased risk of lung cancer in plumbers in British Columbia confirms findings of a study in the United States.[24] Tumours of the pleural cavity were a more frequent cause of death than expected in plumbers in our study. We think that this represents an increased risk of pleural mesothelioma. No increase in the risk of death from leukemia such as that seen in British plumbers[3] was present in the plumbers in our study. The recent change to plastic piping with cemented joints in the plumbing industry may result in changes in the mortality patterns among plumbers, and these should be monitored closely.

The results of our study point to the need for more detailed epidemiologic studies of metal workers in Canada in order to pinpoint factors responsible for their increased risks of death from cancer.

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References

1. FLANDERS WD, ROTHMAN KJ: Occupational risk of laryngeal cancer. *Am J Public Health* 1982; 72: 369–372
2. MILHAM S JR: *Occupational Mortality in Washington State, 1950–1971* (DHEW publ NIOSH 76-175-A-C/G), US Dept of National Health, Education, and Welfare, Washington, 1976
3. *Occupational Mortality: the Registrar General's Decennial Supplement for England and Wales, 1970–1972* (ser DS, no 1), HMSO, London, 1978
4. *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death*, 6th rev, WHO, Geneva, 1948
5. *International Classification of Diseases*, 7th rev, WHO, Geneva, 1957
6. *International Classification of Diseases, Adapted for Use in the United States*, 8th rev (PHS publ no 1693), US Dept of Health, Education, and Welfare, National Center for Health Statistics, Washington, 1967
7. *Occupational Classification Manual, Census of Canada — 1961*, Statistics Canada, Ottawa, 1961
8. MONSON RR: *Occupational Epidemiology*, CRC Pr, Boca Raton, Fla, 1980: 86–87
9. ARMITAGE P: *Statistical Methods in Medical Research*, Blackwell Sci Publ, Oxford, 1971
10. MORIYAMA IM, BAUM WS, HAENSZEL WM, MATTISON BF: Inquiry into diagnostic evidence supporting medical certifications of death. *Am J Public Health* 1958; 48: 1376–1387
11. PETERSEN GR, MILHAM S JR: Hodgkin's disease mortality and occupational exposure to wood. *JNCI* 1974; 53: 957–958
12. DECOUFLÉ P, THOMAS TL, PICKLE LW: Comparison of the proportionate mortality ratio and the standardized mortality ratio risk measures. *Am J Epidemiol* 1980; 111: 263–269
13. KUPPER LL, MCMICHAEL AJ, SYMONS MJ, MOST BM: On the utility of proportional mortality analysis. *J Chronic Dis* 1978; 31: 15–22
14. *Smoking Habits of Canadians* (tech rep ser, no 7), Dept of National Health and Welfare, health protection branch, Ottawa, 1977
15. HIRAYAMA T: Proportion of cancer attributable to occupation obtained from a large cohort study in Japan. In PETO R, SCHNEIDERMAN M (eds): *Quantification of Occupational Cancer* (Banbury rep, no 9), Cold Spring Harbor Lab, Cold Spring Harbor, NY, 1981: 631–649
16. BLOT WJ, BROWN LM, POTTERN LM, STONE BJ, FRAUMENI JF JR: Lung cancer among long-term steel workers. *Am J Epidemiol* 1983; 117: 706–716
17. GIBBS GW, HOROWITZ I: Lung cancer mortality in aluminum reduction plant workers. *JOM* 1979; 21: 347–353
18. MILHAM S JR: *Occupational Mortality in Washington State, 1950–1979*, US Dept of National Health, Education, and Welfare, Washington (in press)
19. GILLMAN JPW, VESSELINOVITCH SD: Cutting oils and squamous-cell carcinoma; an experimental study of the carcinogenicity of 2 types of cutting oils. *Br J Ind Med* 1955; 12: 244–248
20. KIPLING MD, WALDRON HA: Polycyclic aromatic hydrocarbons in mineral oil, tar, and pitch, excluding petroleum pitch. *Prev Med* 1976; 5: 262–278
21. DECOUFLÉ P: Further analysis of cancer mortality patterns among workers exposed to cutting oil mists. *JNCI* 1978; 61: 1025–1030
22. STETTLER LE, GROTH DH, MACKAY GR: Identification of stainless steel welding fume particles in human lung and environmental samples using electron probe microanalysis. *Am Ind Hyg Assoc J* 1977; 38 (2): 76–82
23. HEWITT PJ, HICKS R: An investigation of the effects of inhaled welding fumes in the rat. *Ann Occup Hyg* 1973; 16: 213–221
24. KAMINSKI R, GIESSERT KS, DACEY E: Mortality analysis of plumbers and pipefitters. *JOM* 1980; 22: 183–189