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Lung Cancer Among Steelworkers in Ontario

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A population-based case-control study was carried out to follow up observations of increased lung cancer risk in the steel pouring areas of two Ontario steel mills. Study subjects were all men, aged 45–75 years, who died of lung cancer in the cities of Hamilton or Sault Ste-Marie, Ontario from 1979–1988. Nine hundred sixty-seven lung cancer victims were matched with 2,827 control subjects who died of other causes. Work histones were provided by the employers of steelworkers. In comparison with other residents of their cities, the relative risk of death from lung cancer was 0.85 (95% confidence interval [CI]: 0.58–1.23) for steelworkers in Sault-Ste Marie and was 1.10 (95% CI: 0.89–1.37) for steelworkers in Hamilton. In internal comparisons within the steel companies, increased lung cancer risk was observed among foundry, coke oven, and pouring pit workers. Retrospective hygiene assessment suggested that the increased risk of lung cancer among steel pourers might be related to the use of tar-based mold coating agents or to exposure to mineral fibers. © 1994 Wiley-Liss, Inc.

Key words: lung cancer, steelmaking, epidemiology, industrial hygiene

INTRODUCTION

In 1988, the Ontario Ministry of Labour investigated workers' concerns about a "cancer problem" at an electric arc steelmaking operation and confirmed the existence of a cluster of lung cancer deaths in the melting department of the plant [Finkelstein and Wilk, 1990]. A follow-up investigation at a second mill found that 8 of 30 men who had ever worked in the pouring pit area had died of lung cancer (PMR 276; $p < 0.01$), but increased risk was not found elsewhere in the melting department [Finkelstein et al., 19911. The results of the studies at the two plants, taken together, indicated a strong relationship between employment in the pouring pit areas of the melt shops and an increased risk of lung cancer. The causative factor(s) were not identified. Industrial hygiene assessments found current exposures to carcinogenic metals and silica to be within prevailing guidelines. No polycyclic aromatic hydrocarbons (PAHs) were detected.

A tripartite (labor-management-government) committee was struck to investigate lung cancer risk in other Ontario steel mills. The aim of the investigation was to answer two questions: 1) Are Ontario steelworkers at increased risk of lung cancer

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compared to other members of the Ontario population?; and, 2) Is there any association between particular work areas or activities in steel plants and an increased risk of lung cancer? The methods included a population-based case-control study of lung cancer in two major steelmaking cities and collection and analysis of historic hygiene information. This report presents the findings.

MATERIALS AND METHODS

Much of the Ontario steel industry is located in the cities of Hamilton and Sault-Ste Marie. In Sault Ste-Marie, a large integrated steel producer is the leading employer in the city. In Hamilton, attention was focused on two major employers (a third had been the subject of the initial cluster investigation). Both plants were integrated steel producers employing more than 10,000 workers. At one of the plants there was a substantial foundry operation. For reasons of economy and speed, a modified case-control methodology was adopted.

Study Subjects

It was the aim of the study to identify all deaths from lung cancer, in the cities of Hamilton and Sault Ste-Marie, among men 45–75 years of age, during the years 1979–1988. A computer file available to the Ministry of Labour was used to identify men who died of lung cancer in the years 1979–1983. There were 105 lung cancer deaths in Sault Ste-Marie and 505 in Hamilton. Each lung cancer victim was randomly matched with two other men of the same age, from the same city, who died in the same year, of any cause other than lung cancer. The Ontario Cancer Treatment and Research Foundation (OCTRF) was commissioned to provide similar data for 1984–1988 from a mortality tape in its possession. In the period 1984 through mid-1988, there were 91 lung cancer deaths in Sault Ste-Marie and 485 in Hamilton. During the data analysis phase of the study, it was discovered that the OCTRF had provided more control subjects (219 controls from Sault Ste-Marie and 2,000 controls from Hamilton) than had been requested. Since this was an unbiased selection (and since the death certificates had already been abstracted), the additional controls were retained in the study to increase the statistical power.

Steel Industry Employment

The job and industry fields on the death certificates were abstracted. On some certificates, there was either no occupational information recorded, or what was reported (e.g., retired, disabled) was not useful. This occurred for 19(3%) subjects in Sault Ste-Marie and 684(17%) subjects in Hamilton. There is a substantial (unexplained) difference in the rates of recording occupational data between the two cities, but within each city there was no difference in recording rates between cases and controls, or between the two time periods. All subjects without adequate occupational information on the death certificate were excluded from further analysis.

The job and industry titles were examined for association with the steel industry. All study subjects whose death certificates mentioned "steelworker" or the name of a steel company were classified as steelworkers for the lung cancer risk analysis. Lists of all such subjects were prepared, and the employers were asked to search for job histories for the individuals on the lists. Usable work histones were located for 216(93%) of the 232 steelworkers in Sault Ste-Marie. In Hamilton, one employer was

able to locate job and smoking histories for all 90 men on its search list, plus an additional 29 steelworkers for whom an employer had not been specified on the death certificate. The second employer located job histories for 239 (92%) of the 261 men on its list. Only 1 of the 22 men without a job history was a lung cancer victim. In addition, 88 men on the list of "steelworkers with unidentified employer" were identified and job histories were provided by this employer.

A Priori Suspect Work Areas

On the basis of existing knowledge about known or suspected lung cancer risk, a number of departments were selected beforehand for special examination. These were the steel pouring areas, (because of the earlier observations at the two steel plants described in the Introduction), the coke oven departments, and the foundry department at one Hamilton steelmaker where an increased lung cancer risk had earlier been described [Gibson et al., 19771. The risk of lung cancer among workers in the target areas was compared to the risk of lung cancer among workers from other areas of the same plant.

Retrospective Hygiene Assessment of Steel Pouring Areas

Because the agent(s) responsible for the increased lung cancer risk at the two plants previously investigated had not been identified, hygienists at the three additional mills were asked to prepare historical overviews of the materials and methods in the steel pouring areas of their operations. This was done by review of old records and discussions with long-serving employees.

Statistical Analysis

Odds ratios (relative risks) and confidence limits were computed by Exact and Asymptotic stratified 2 x 2 table analysis [SERC, 19881. In the analysis which compared lung cancer risk among steelworkers to that among other residents of their cities, study subjects were divided among three age strata (45–54, 55–64, and 65 years of age or more) and two time periods (death in 1979–1983 or 1984–1988). In the analysis by company, study subjects were divided among two age strata (less than 65, and 65 years of age or more) and two time periods.

The use of deceased control subjects for the estimation of lung cancer risk in the steel industry will produce valid results only if employment in the steel industry is not associated with either increased or decreased mortality from causes of death other than lung cancer [Finkelstein and Liss, 19871. It is known that mortality rates in Canada vary with social class and occupation [Howe and Lindsay, 19831. In order to ensure comparability, the steelworkers were compared to other blue collar workers, as well as to all other city residents.

RESULTS

Table I shows the relative risk of lung cancer among steelworkers compared to other residents of their cities. In Sault Ste-Marie, the relative risk was 0.85 and in Hamilton it was 1.10. Neither was significantly different from 1.0. Restricting comparison to workers with blue collar occupations had minimal effect on the risk estimates.

Because of the small size of the study population, the statistical power to

TABLE I. Lung Cancer Risk Among Steelworkers Compared to Other Residents of Their Cities

	Cases		Controls			
Citv	Steelworker	Not steelworker	Steelworker	Not steelworker	Relative risk[a]	95% CI[b]
Comparison population is all city residents						
Sault Ste-Marie	73	117	168	241	0.85	(0.58–1.23)
Hamilton	145	632	417	2001	1.10	(0.89–1.37)
Comparison population is city residents in blue collar occupations						
Sault Ste-Marie	71	82	166	172	0.87	(0.58–1.31)
Hamilton	141	515	394	1524	1.08	(0.86–1.35)

[a]Adjusted for age and time period.
[b]CI, confidence interval.

investigate lung cancer risk by work area within the individual plants was low. Some of the larger departments and those areas where increased risk had previously been identified were examined. Table II shows the results of these internal comparisons.

There was no increased risk of lung cancer among coke oven workers in Sault Ste-Marie, but an increased risk was present among coke oven workers at Plant 2 in Hamilton. At this plant, five of the seven men who had ever worked at the coke ovens died from lung cancer (relative risk = 7.03). Among the workers from Plant 1 in Hamilton, only two had been employed at the coke ovens, and neither man died from lung cancer.

At the blast furnace, the next downstream operation in the steelmaking process, lung cancer risk was increased at two of the three plants. At the third, there were no lung cancer deaths among five men who had worked in the blast furnace department.

Downstream of the blast furnace are the steelmaking furnaces (open hearth, basic oxygen, and electric arc). Lung cancer risk was elevated at Hamilton Plant 1, but not at the others, and overall, there was no increase in risk.

The steel pouring areas are work areas where an increase in lung cancer risk had previously been found at two Ontario plants. In Sault Ste-Marie, four workers had been employed as steel pourers for 5 years or more. There were no cases of lung cancer among them. At Plant 2 in Hamilton, four workers had been employed as steel pourers for 5 years or more and there were two deaths from lung cancer. The relative risk was 2.8 in comparison to other employees of the plant. There were no steel pourers among the population sample from Hamilton Plant 1.

Finally, Table II shows the findings for the foundry at Hamilton Plant 1. Twelve of the 33 men who had worked in the foundry died of lung cancer (relative risk 1.9).

DISCUSSION

The present study was performed to follow up previous observations of an increased risk of lung cancer among workers in the steel pouring areas of two electric arc steelmaking operations. The aims of the study were to assess the lung cancer mortality risk of steelworkers, in general, and to determine, among the major Ontario employers, the lung cancer experience of workers in areas previously identified as being at increased risk. In addition, through the collection of historical hygiene information, we hoped to collect clues about the possible etiologic agent(s) responsible for the increased risk in the steel pouring areas.

TABLE II. Lung Cancer Risk by Work Area: Internal Comparisons at the Major Steel Plants.

Work area	Cases: Target area	Cases: Other work area	Controls: Target area	Controls: Other work areas	Relative risk	95% CI[a]
Coke ovens: 5 years or more						
Sault Ste-Marie	2	63	5	146	0.97	(0.1–6.2)
Hamilton: Plant 2	3	78	5	249	1.78	(0.3–9.3)
Combined	5	141	10	395	1.37	(0.4–4.5)
Blast furnace workers: 5 years or more						
Sault Ste-Marie	6	59	9	142	1.54	(0.4–5.1)
Hamilton: Plant 1	0	30	5	84	0	
Hamilton: Plant 2	5	76	8	246	2.00	(0.5–7.2)
Combined	11	165	22	472	1.38	(0.61–3.06)
Electric, open hearth, and basic oxygen furnaces: 5 years or more						
Sault Ste-Marie	6	58	15	136	1.14	(0.4–3.1)
Hamilton: Plant 1	3	27	4	85	2.36	(0.4–13.6)
Hamilton: Plant 2	8	73	33	221	0.79	(0.3–1.9)
Combined	17	158	52	442	0.92	(0.5–1.7)
Pouring pit workers: 5 years or more						
Sault Ste-Marie	0	65	7	144	0.0	(0–1.9)
Hamilton: Plant 2	2	79	2	252	2.8	(0.2–41)
Foundry: 5 years or more						
Hamilton: Plant 1	12	18	21	68	1.94	(0.7–5.2)

[a]CI, confidence interval.

Because of financial and time constraints, a population-based case-control methodology was adopted. All lung cancer deaths occurring during a 10-year period among residents of two steelmaking cities were identified, along with a random sample of men dying from other causes. There were a number of potential sources of bias. Employment as a steelworker was identified from information recorded on the death certificate. Since the occupations of men dying from other causes were used as a comparison for the occupations of lung cancer victims, an unbiased comparison requires no correlation between the cause of death and the likelihood that a worker is identified as a steelworker on the death certificate. It seems reasonable to assume that this condition would be satisfied. Secondly, only those steelworkers who were resident in the cities in which the plants were located were included in the study. It also seems reasonable to presume that there should not be a strong differentiation in causes of death between those steelworkers residing in the target cities and those residing in surrounding communities. Finally, men who died from other causes were used as control subjects for the lung cancer victims. This could result in bias if increased or decreased overall mortality risk made certain individuals more or less likely to appear in the pool of potential controls. Adjustment for blue collar status had little effect on the odds ratios, and there is no strong association known between workplaces in the steel mills and increased or decreased mortality risk from causes other than lung cancer.

The major study of the health of steelworkers is the mammoth investigation, carried out at the University of Pittsburgh, of some 59,000 Allegheny County steel-

workers and 10,000 non-Allegheny coke plant workers [Redmond et al., 1981]. That study demonstrated that coke oven workers had an increased risk of lung cancer in comparison with other steelworkers and it was also found that the Allegheny County steelworkers, as a whole, had increased lung cancer rates in comparison with the general population of the United States. During the period 1953–1975, lung cancer mortality rates were increased by 35% among white workers and 69% among black workers. The interpretation of this finding is unclear because, in an earlier analysis of mortality during the period 1953–1966, [Redmond and Breslin, 1975], the authors found that lung cancer mortality rates in the steelworker population were similar to those of other men in Allegheny County, although they were significantly elevated in comparison with all U.S. males. A similar comparison is not reported in the 1981 paper, nor is it reported what proportion of the Allegheny County population is composed of men who had worked in the steel industry.

In a second American investigation, researchers from the National Cancer Institute interviewed the relatives of men who had died of lung cancer in an industrialized area of eastern Pennsylvania to determine whether employment in the steel industry was a risk factor for lung cancer [Blot et al., 1983]. A significantly increased risk was found, primarily among long-term employees. Adjusted for cigarette smoking, the risk for steelworkers was found to be increased by 80% (95% confidence interval [CI]: 20–180% increase). The increase was higher among steelworkers who had worked in foundry operations but was seen for broad categories of jobs within the industry.

In the present analysis, it was found that the risk of lung cancer among steelworkers in Sault Ste-Marie was less (0.85) than that of other men in the city. In Hamilton, the relative risk was 1.1. This increase was not statistically significant, but is probably a true excess because it is attributable to increased lung cancer risk in a priori high risk work areas, namely, the coke ovens, the steel pouring area at Plant 2, and the foundry at Plant 1.

The analysis by work area in this study did not have the statistical power to identify any new high risk occupations, but it did permit assessment of risk in previously identified hazardous areas as well as an estimation of the size of the population at risk. This estimate is important since the amount of disease produced by a workplace hazard depends upon both the size of the risk factor and the proportion of the population exposed to the hazard. A moderate relative risk applicable to a high proportion of the population would produce more cases of disease than a high relative risk applicable to only a small proportion of the population. The proportion of cases occurring in the worker population which can be explained by the risk factor is called the population attributable risk [Breslow and Day, 1980].

The Pennsylvania studies [Redmond et al., 1981] identified the coke ovens as an area of increased lung cancer risk. We found no lung cancer excess among coke oven workers in Sault Ste-Marie, but the relative risk was 1.8 among workers at Plant 2 in Hamilton. From the control series one can estimate the proportion of the plant population exposed in this work area (5 [2%] of 254 control subjects: 95% CI 0.6%–4.5%). Calculation of the population attributable risk indicates that about 2% of the lung cancers arising in the Plant 2 population might be attributable to coke oven exposures.

Gibson et al. [1977] studied mortality during 1967–1976 among employees of one of the plants in the present study (Hamilton: Plant 1). All cause standardized

mortality ratios were less than 100. There were 32 deaths from lung cancer while 25 were expected. In the group of 439 men who had worked for 5 years or more in foundry operations, there was a 2.5-fold excess of lung cancer mortality, while among the 1,100 other men there were fewer lung cancer deaths than expected.

In the present study, it was possible to estimate the risk of lung cancer death, during the period 1979–1988, attributable to foundry employment. In comparison to other plant employees, men with 5 or more years of foundry employment experienced a lung cancer risk elevated 1.9-fold (95% CI: 0.7–5.2). Twenty-one (24%) of 89 control subjects were foundry workers. From the population attributable risk, it is estimated that about 18% of the lung cancers arising in the Plant *2* population might be attributable to foundry exposures. Thus, although the lung cancer relative risk among foundry workers at Plant 1 is similar in size to the lung cancer relative risk for coke oven workers at Plant 2, the foundry exposures are implicated in more cases of disease because of the larger size of the population exposed.

The work areas of particular interest in this investigation were the pouring areas of the steelmaking departments. There were no steel pourers among the population sample from Hamilton Plant 1. There were no lung cancer deaths among four men who had been employed in the steel pouring areas in Sault Ste-Marie for 5 years or more, but two of the four men from Plant 2 in Hamilton who had worked as steel pourers died from lung cancer (relative risk: 2.8). This result is not statistically significant, but is consistent with the findings in the two previous investigations. A description of the processes taking place in the steel pouring areas follows.

After a heat of steel is refined in a steelmaking furnace, the liquid steel is tapped into the refractory-lined steel ladle [US Steel, 19641. The ladle is moved by overhead crane to a pouring platform where the steel is poured into a series of molds of the desired dimensions. The steel solidifies to form a casting called an ingot. In recent years, much of ingot casting has been replaced by the continuous casting process.

When molten steel cools to the temperature range in which it begins to solidify, the solubility of gases dissolved in the steel decreases and the excess gases are expelled from the metal. Gaseous evolution can have undesirable effects upon the structure of the solidified ingot and a variety of methods are used to control it. These include the addition of materials to the furnace and the ladle, as well as antioxidants such as aluminum to the molds. Other methods to control the structure of the ingot included the use of metal caps or refractory "hot tops."

Ingot molds commonly used were tall box-like containers made of cast iron. In top-poured ingots, splashes could solidify on the lower part of the mold walls, producing defects on the ingot surfaces. One method of reducing the effects of splashing was to coat the inside of the molds with a substance that would volatilize and tend to repel splashes. Many substances were tried for this purpose including tar, powdered pitch, and graphite. Tar was probably the most effective splash repellant, but if used under unsuitable conditions, it gave rise to annoying fumes [US Steel, 1964].

The materials and methods used in the steel pouring areas of the Ontario plants were reviewed by hygienists. At Sault Ste-Marie, the primary function of the steel pourers was the pouring of steel ingots. They also set stoppers in the ladles and were involved in the cleaning of the ladles and pit areas. A tar-based product was applied to the molds until the late 1940s. This was later replaced by a product containing graphite and molasses. Hot top compounds consisted primarily of aluminum and

aluminum oxide. During the 1960s, mould liner boards containing amorphous silica, aluminum oxide, and iron oxide were introduced.

At Hamilton Plant 1, ingot mold liners and hot top compounds were used when making "killed" steel. Prior to the late 1960s, the mold liners consisted of a metal sheet lined with fireclay bricks. Hot top compounds included aluminum oxide and graphite. Ingot mold washes were used since operations began. Originally these consisted of a tar-based material. In the 1960s, a switch was made to a mixture of organic and sodium salts dissolved in an ethylene glycol-water solution.

At Hamilton Plant 2, refractory bricks and clay were used on hot top molds. Liner boards contained up to 6% asbestos until the mid 1970s, when asbestos was replaced with ceramic or cellulose fibers. Ingot molds were sprayed with tar until 1975 when a switch was made to a wash containing silica and ethylene glycol. Fumes containing PAHs were released when steel was poured into the tar-coated molds.

Asbestos-containing products were in wide use in the steel pouring areas. These included gloves and other protective clothing, and asbestos blankets. At one of the plants studied previously [Finkelstein et al., 19911, asbestos blankets were used to cover the ladle, and charred blankets were often discarded on the pouring pit floor.

Review of the hygiene information suggests that the likely candidates for the cause of the lung cancer hazard in the steel pouring areas were the fumes or dusts from the tars coating the ingot cases. PAHs were present in the fumes during pouring. It was also common practice to use compressed air to clean the molds after the ingots had been stripped. It is thus possible that there was exposure to PAH-containing particulate as well.

Tar washes were documented to have been used in four of the five steel plants investigated. There are no measurements of worker exposure to fumes in any of the plants, and the use of tar has been discontinued in all of them. There were no lung cancer victims among the few subjects who had been steel pourers in the plant at Sault Ste-Marie. The use of tar was discontinued in this plant during the 1940s, but the sample size is too small to attribute the absence of increased lung cancer risk to the discontinuation of tar washes. Ironically, there is no record of tar having been used at the plant at which the original cluster was recognized. Hygienists could recall only the use of graphite washes, but there was no documentary information about materials used prior to the early 1970s. Given the practices prevalent in the industry at the time, it is likely that tar had earlier been used in this plant as well.

Asbestos was widely present in the protective equipment used in the pouring areas and it is conceivable that exposure to asbestos played a role in the development of lung cancer. It is known that gloves and other equipment can shed asbestos fibers, but personal exposures were not likely to have been high.

CONCLUSIONS

Steelworkers in the City of Sault Ste-Marie had a risk of death from lung cancer that was lower than the risk among other residents of the city. In Hamilton, the risk of death from lung cancer was about 8% higher than the lung cancer risk among other blue collar workers in the city. Although not statistically significant, this excess risk is attributable to increased risk among foundry, coke oven, and pouring pit workers, groups previously recognized to be at increased risk of lung cancer.

Review of historic processes and materials in the steel pouring areas suggests

that the increased risk of lung cancer might be attributable to the historic use of tar washes on the molds, a practice which has been discontinued in all Ontario plants. Current hygiene assessment finds exposures to carcinogenic metals, PAHs, and silica to be within prevailing guidelines. An anonymous reviewer has pointed out that, historically, the ingredients of hot tops and mold release systems were closely guarded trade secrets, and suggests that hot tops, for example, might have contained asbestos, synthetic mineral fibers, and silica. Continued vigilance is indicated. Because of "the growing evidence linking ceramic fibers to cancer, and the continuing controversy over the carcinogenic effects of silica, we cannot be certain that the risk of lung cancer has been eliminated in these operations."

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