Lung Cancer Among Welders

James J. Beaumont, Ph.D., and Noel S. Weiss, M.D.

Deaths from lung cancer among 3,247 welders in western Washington during the period 1950 through 1976 were identified. Relative to those among men of comparable age and race in the population as a whole, lung cancer mortality rates among the welders were elevated by 32% (p = 0.06). When the analysis was restricted to the period beginning 20 years after first employment, the excess was 74% (p < 0.001). An excess was also found when welders were compared to nonwelders in the same union: the attributable risk was 23.1 per 100,000 per year. A review of 11 published studies showed that most demonstrate an excess risk, with 6 of the 11 showing an excess in the range of 30 to 50%.

Welders are exposed to a variety of substances that are produced during the welding process (Table 1). The content of the fume is dependent upon the type of metal being welded; the presence, if any, of coatings such as paint or galvanizing on the metal; the content of the rods and fluxes; and the kind of shielding used to protect the weld from oxidation. Some of the more common fume components and their respective known health effects are as follows: iron oxide — lung deposits thought to be benign siderosis; zinc oxide — acute reactions known as "metal fume fever"; lead oxide — anemia and nervous system damage; chromium oxide — irritation to the skin, eyes, and mucous membranes; carbon monoxide — chemical hypoxia; and nitrogen oxides and ozone — respiratory irritation and diminished resistance to bacterial pneumonias.

Because of the many respiratory exposures, there has been concern about the potential for excess lung cancer and other respiratory diseases in welding populations.[1-11] To further assess the lung cancer mortality of welders, a cohort of 3,247 men was selected from Local 104 of the International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers and Helpers in Seattle, Wash. These welders worked in a variety of industries: primarily shipbuilding, field construction, and metal fabrication shops. They were part of a larger study population for which many causes of death have been examined previously.[7] The purpose of this report is to focus on the lung cancer experience of the welders in that study and to review lung cancer in welders.

From the Industrywide Studies Branch, Division of Surveillance, Hazard Evaluations and Field Studies, National Institute for Occupational Safety and Health, 4676 Columbia Pkwy., Cincinnati, OH 45226 (Dr. Beaumont), and the Department of Epidemiology, School of Public Health and Community Medicine, University of Washington, Seattle, WA 98195 (Dr. Weiss).

Presented at the International Metalworkers' Federation Conference on Health Hazards in Welding, November 5-6, 1980, at Linden Hall, in Dawson, Pa.

Methods

Welders who were union members for a minimum of three years, including at least one day between January 1, 1950, and December 31, 1973, were the subjects of the study. Their vital status was determined as of January 1, 1977; ascertainment of vital status for those not still working or receiving pension benefits on that date was sought from the Social Security Administration. Deaths were coded by State of Washington nosologists according to the revision of the International Classification of Diseases in effect at the time of death. The lung cancer deaths included in the analysis were those in Code 162 of the Eighth Revision and Codes 162 and 163 of the Sixth and Seventh revisions.

Table 1. — Environmental Exposures Encountered by Welders During Combustible Gas, Covered Electrode Arc, and Gas Shielded Arc Welding.

Metals*	Gases	Miscellaneous
Iron	Carbon monoxide	Fluorides
Lead	Nitrogen oxides	Hydrocarbons
Zinc	Ozone	Silica
Cadmium	Phosgene	UV radiation
Chromium		
Mercury		
Copper		
Aluminum		
Manganese		
Nickel		

*Usually in oxidized form

Table 2. — Distribution of Welders by Year of Entrance to Boilermakers Local 104.

Year of Entrance	No. of Welders
1910-1919	14
1920-1929	1
1930-1939	53
1940-1949	1114
1950-1959	457
1960-1969	1273
1970 +	335
Total	3247

Person-years were calculated for five-year age and time categories, and multiplied by the corresponding age- and time-specific U.S. mortality rates to yield expected numbers of deaths. Calculations were performed with a modified life table computer program.[12] Observed numbers were divided by expected numbers to calculate standardized mortality ratios (SMRs) which were assessed for statistical significance by the equation:

$$\frac{(|0 - E| - 0.5)^2}{E} = \chi^2_{(1)},$$

where 0 = number observed and E = number expected. This test is based upon the Poisson approximation to the binomial distribution where the expected number of events is the variance.[13 14 15]

Approximate 95% confidence limits were calculated for the graphical presentations as follows:

$$\text{lower limit} = \text{SMR} \times \exp(-1.96\sqrt{0})$$
$$\text{upper limit} = \text{SMR} \times \exp(+1.96\sqrt{0})$$

where 0 = the number of deaths observed.[14]

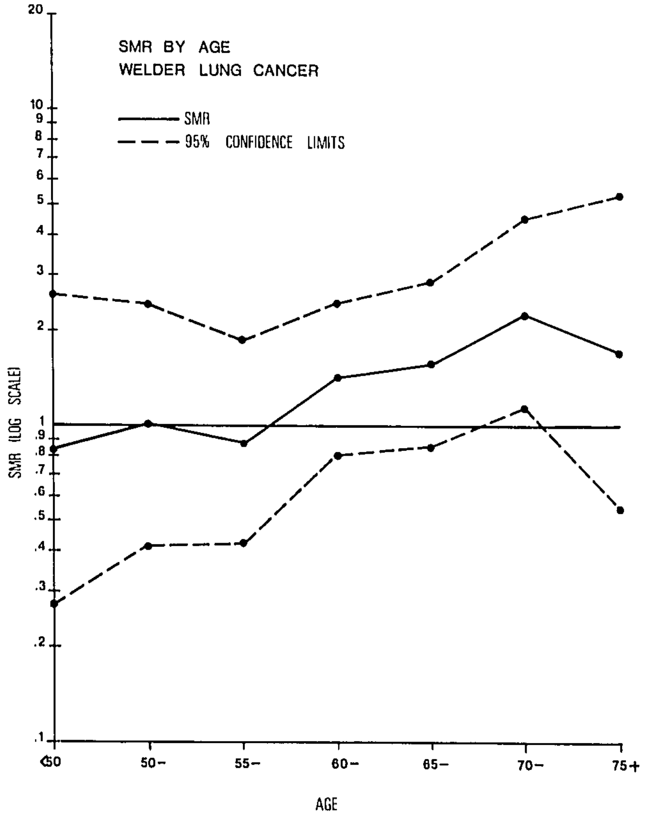

Fig 1. — Welder lung cancer by age at risk (standardized mortality ratios with 95% confidence limits; based upon 50 deaths, 43,670 person-years).

Table 3. — Vital Status and Method of Initial Status Ascertainment for the Welders in Boilermakers Local 104.

Status	No.	%
Alive	2649	82
Still working	1165	36
Pensioned	277	9
Social Security	1207	37
Deceased	529	16
Known to Union	326	10
Social Security	203	6
Unknown	69	2
Total	3247	100

U.S. death rates for white males, specific for age and calendar time, were used to calculate expected numbers of deaths. Though race was not recorded by the union, senior union officials and staff report that the workers were almost exclusively white during the 24-year cohort establishment period. U.S. rates were chosen over local rates due to their availability (they were supplied with the mortality analysis computer program) and because rates of death due to lung cancer among white males were very similar for King County and for the nation as a whole (38.8 vs. 38.0 per 100,000, respectively, for the period 1950 through 1969).[16]

Internal comparisons of lung cancer rates among the welders and among 5,432 nonwelders from Local 104 were performed to test the hypothesis that welders may have been at greater risk of lung cancer than other members of the local. Comparison was made first of the latency-specific (interval from first employment) stan-

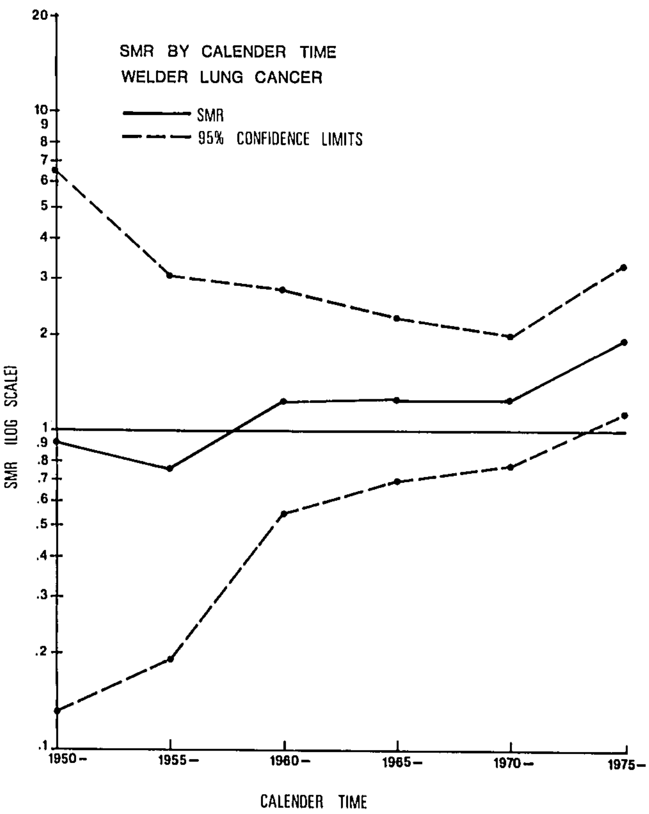

Fig 2. — Welder lung cancer by calendar time period at risk (standardized mortality ratios with 95% confidence limits; based upon 50 deaths, 43,670 person-years).

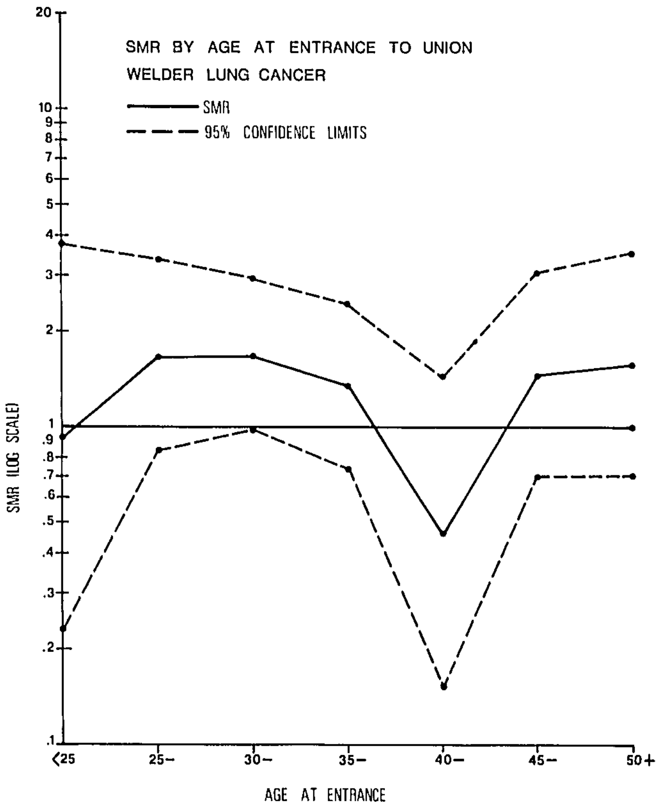

Fig 3. — Welder lung cancer by age at entrance to Boilermakers Local 104 (standardized mortality ratios with 95% confidence limits; based upon 50 deaths, 43,670 person-years).

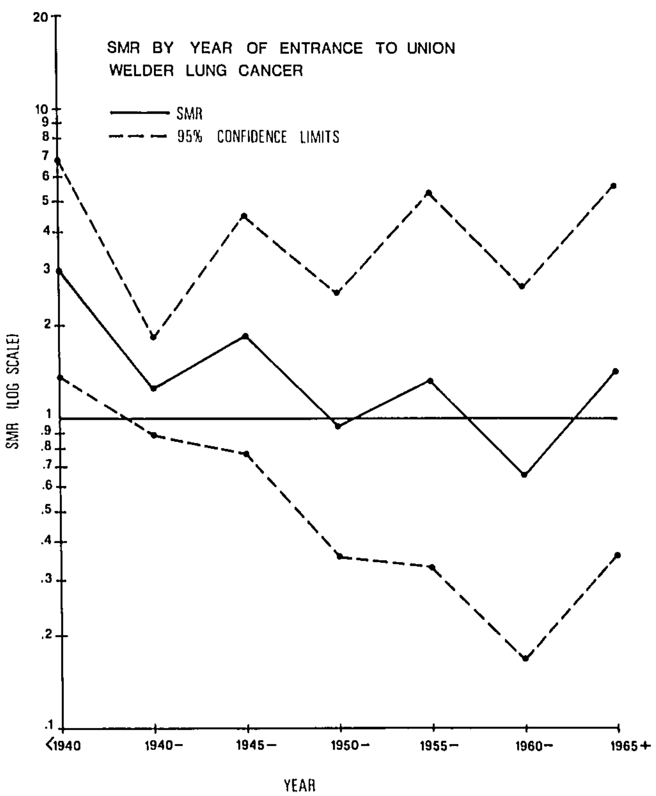

Fig 4. — Welder lung cancer by year of entrance to Boilermakers Local 104 (standardized mortality ratios with 95% confidence limits; based upon 50 deaths, 43,670 person-years).

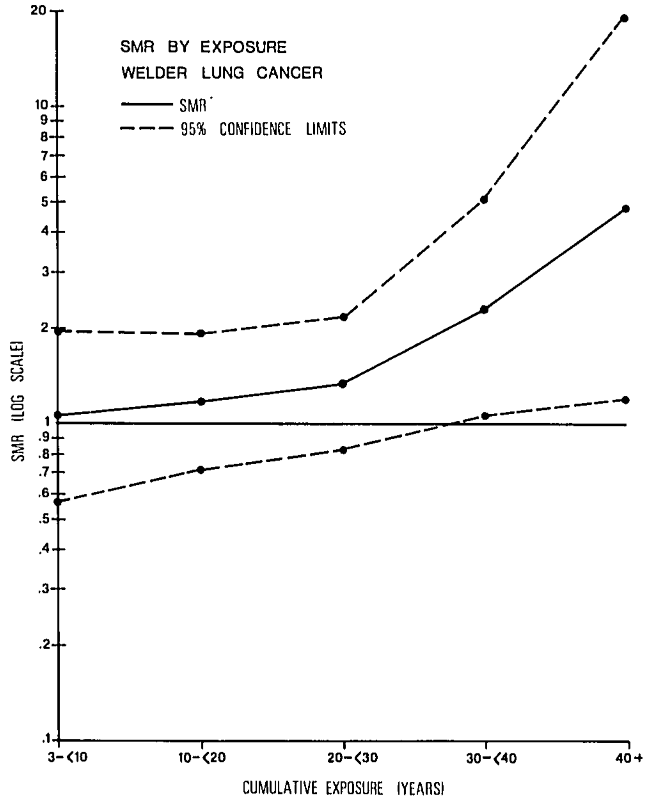

Fig 5. — Welder lung cancer by exposure where exposure is the cumulative membership time since entry to the union (standardized mortality ratios with 95% confidence limits; based upon 50 deaths, 43,670 person-years).

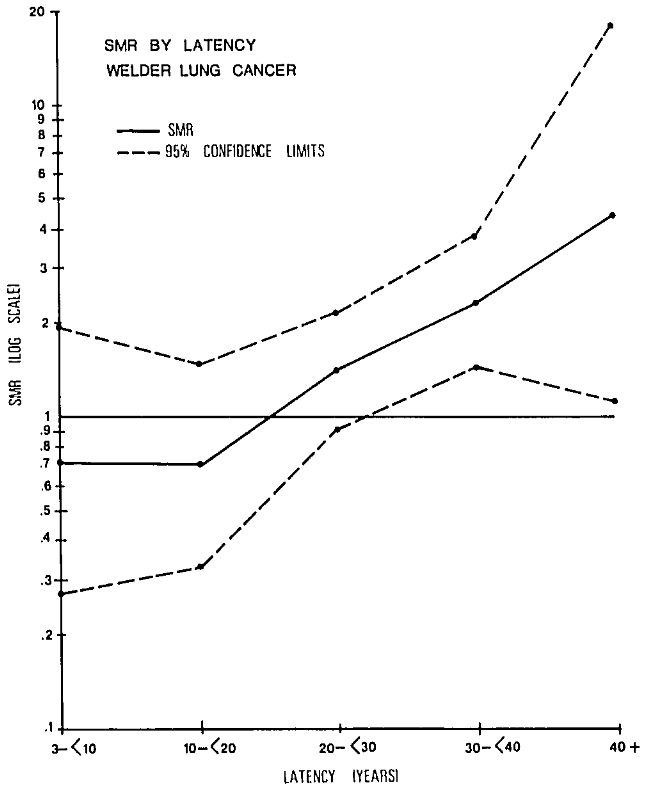

Fig 6. — Lung cancer latency in welders where first exposure is entry to the union (standardized mortality ratios with 95% confidence limits; based upon 50 deaths, 43,670 person-years).

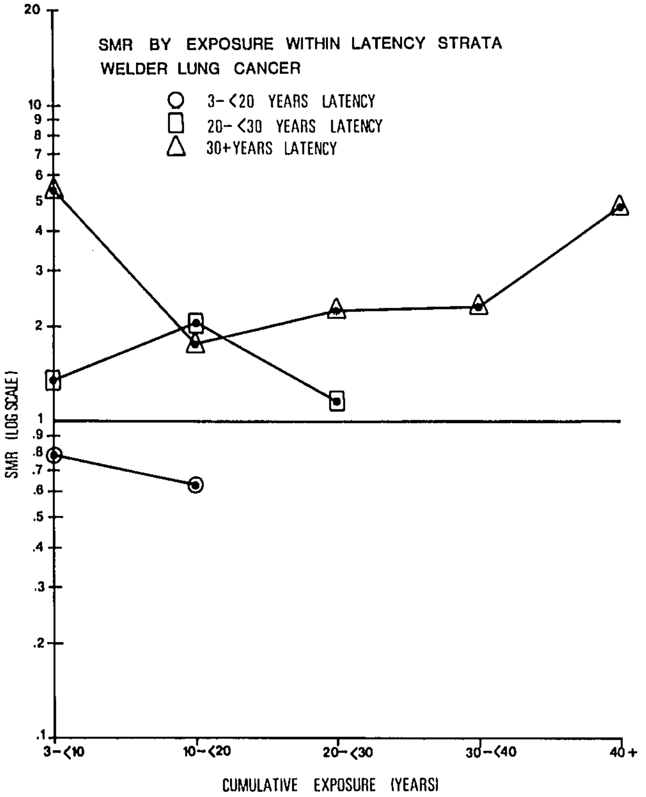

Fig 7. — Welder lung cancer by cumulative exposure within latency strata (standardized mortality ratios; based upon 50 deaths, 43,670 person-years).

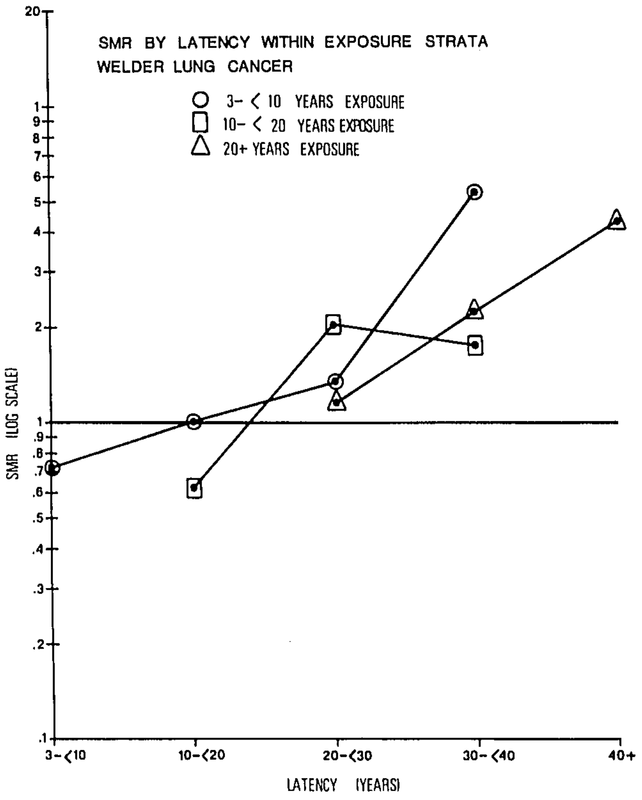

Fig 8. — Welder lung cancer by latency within exposure strata (standardized mortality ratios; based upon 50 deaths, 43,670 person-years).

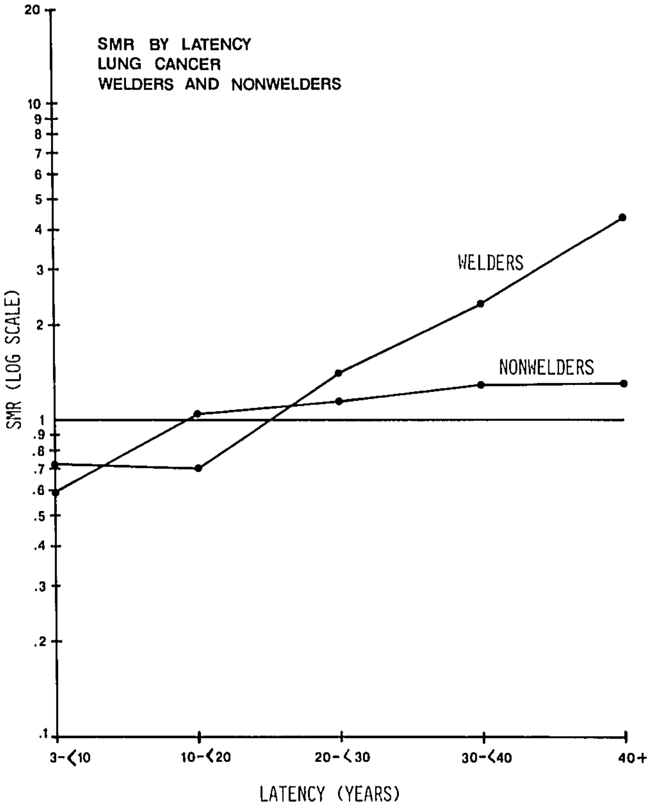

Fig 9. — Lung cancer in welders and nonwelders in Local 104: standardized mortality ratios by latency where first exposure is entry to the union.

dardized mortality ratios, for which the expected numbers of deaths were derived from U.S. statistics. While it would have been preferable to compare latency-specific results among welders and nonwelders directly, adjustment for age and time was not possible because comparable numbers of person-years and observed deaths were not simultaneously available for age, time, and latency. It was possible, however, to make a direct comparison of the overall (no latency breakdown) lung cancer rates: five-year age- and time-specific rates among the nonwelders were weighted by the corresponding numbers of person-years among welders to yield rates for nonwelders that were comparable.[17]

Results

The distribution of the 3,247 welders by year of entrance to the union is given in Table 2, where it can be seen that many of the welders joined the local in the 1940s, reflecting an increase in shipyard employment that occurred during World War II. Follow-up showed that 529 (16%) were deceased as of the study cutoff date, January 1, 1977 (Table 3). Fifty of the deaths were due to lung cancer when only 37.95 were expected on the basis of U.S. statistics (SMR = 1.32, $p = 0.06$). When only deaths occurring 20 or more years from first employment were considered, the observed and expected figures were 39 and 22.38, respectively (SMR = 1.74, $p < 0.001$).

The excess risk of lung cancer was examined by age at risk; calendar time; age started work; year started work; duration of exposure; and latency, which was defined as interval from first employment (Figs 1 to 6). Both age at

Table 4. — Comparison of Welders and Nonwelders with Regard to Average Age and Year of Entry to Boilermakers Local 104.

	Welders	Nonwelders	Difference
Age of entry	32.0	33.8	1.8
Year of entry	55.6	52.3	3.3

risk and calendar time exhibited a positive trend which may be explained by the fact that person-years that represent older age and later time are also higher in cumulative exposure and latency. Year of entrance to the union demonstrated a negative trend, which may similarly be due to the fact that workers initially exposed further back in time had longer latency periods within which to develop cancer and, on the average, had longer cumulative exposures.

Length of exposure and latency were strongly associated with excess risk for lung cancer, as can be seen in Figs 5 and 6. These two variables were very highly correlated with each other, however, because as the duration of exposure increased for an individual the latency increased simultaneously (the correlation was not perfect because exposure stopped accumulating when the worker stopped working, while latency continued to accumulate). The curve for duration of exposure could therefore have been due to a latency effect and, conversely, the latency curve could have been due to the effect of duration of exposure. To accurately assess the importance of one variable it was necessary to control for the effect of the other, as shown in Figs 7 and 8. In Fig 7, where duration of exposure was examined within latency strata, it can be seen that there was no longer a clear trend. When latency was looked at within duration of exposure strata (Fig 8), however, its effect remained strong. The association of excess lung cancer risk with length of exposure among welders (Fig 5) appears, therefore, to have been an artifact caused by the high correlation of length of exposure with latency.

Welders were compared to other ("nonwelder") members of Local 104 to determine whether their risk of lung cancer was any greater, the hypothesis being that exposure to cigarette smoking and occupational factors other than welding were probably similar, and that the lung cancer rates should also be similar if welding fumes had no effect. Comparison of standardized mortality ratios by latency (Fig 9) demonstrated no excess in either group until 20 years from first exposure, after which the excess risk rose at a much greater rate among the welders. While indirectly standardized mortality ratios are not strictly comparable between job categories if the age and time distributions of the person-years are different (and the excess risk varies with age and time), it can be seen in Table 4 that welders and nonwelders were fairly similar with respect to these variables.

Direct comparison (with no reference to U.S. statistics) was performed by adjusting the lung cancer rate among nonwelders by age and time to make it comparable to that of welders. The attributable risk, calculated by weighting the risk difference in each age-time stratum by the variance of the effect estimate for that stratum,[17] was 23.1 lung cancers per 100,000 welders per year, with lower and upper 95% confidence limits of −11.2 and 57.5 per 100,000 respectively. The similarly weighted relative risk

Table 5. — Studies That Have Examined the Risk of Lung Cancer in Welders, Arranged in Order of Decreasing Relative Risk.

Primary Author	Year	No. Studied	Design	Source of Population	Relative Risk
Breslow[1]	1954	493 lung cancers 493 controls	Case-control	California hospitals	7.67* ($p < 0.01$)
Registrar general[2]	1978	117,140 welders	Cross-sectional	England & Wales population	1.51 ($p < 0.01$)
Redmond[3]	1979	646 welders	Historical prospective	Pennsylvania steel companies	1.51† ($p < 0.05$)
Menck[4]	1976	15,300 welders	Cross-sectional	Los Angeles population	1.37 ($p < 0.05$)
Milham[5]	1976	1376 welder deaths	Proportionate mortality	Washington state	1.36 ($p < 0.05$)
Blot[6]	1980	336 lung cancers	Case-control	Coastal Virginia	1.32‡
Beaumont[7]	1980	3247 welders	Historical prospective	Seattle union	1.31§
Dunn[8]	1960	10235 welders	Historical prospective	California unions	1.05
Peterson[9]	1980	863 welder deaths	Proportionate mortality	California state	0.99
Decoufle[10]	1978	118 lung cancers 238 controls	Case-control	New York hospital	0.92
Blot[11]	1978	458 lung cancers 553 controls	Case-control	Coastal Georgia	0.67¶

*Smoking adjusted
†In comparison to U.S. rates. In comparison to other steelworkers the relative risk was 1.13
‡Shipyard welding prior to 1950 among all lung cancer deaths and controls in the Tidewater region of Virginia. When the analysis was restricted to shipyard workers only, the relative risk was 1.04
§All respiratory cancer
¶This was for shipyard welding in 11 countries

estimate was 1.28, with lower and upper 95% confidence limits of 0.89 and 1.84, respectively.

Discussion

Lung cancer was in excess among Local 104 welders: the overall increase was 32% relative to the U.S. population, and when only the person-years at risk 20 or more years from first employment were considered, the excess was 74%. These findings are compatible with those from previous studies: when the risk ratios from all 11 studies of lung cancer among welders are ranked by their magnitude, the ratio of 1.31 from the present study is just below the median value. Table 5 lists, in descending order of relative risk found, the studies of lung cancer among welders; a dotted line divides the relative risks above 1.00 from those below 1.00. It can be seen that most of the studies demonstrate an excess risk, with 6 of the 11 showing an excess in the range of 30 to 50%.

A latency (interval from first employment) effect was seen, but the excess risk was also associated with length of exposure, age at risk, calendar time, and year started working. Because of the interdependency of these variables it could be argued that the latency effect was really an age effect, for example, or that any one variable caused the others to be artifically associated with excess disease risk. The latency effect was probably real, however, because it was by far the strongest trend and could not be explained by correlation with variables that exhibited weaker associations. It is possible that latency explained most of the associations seen for the other variables, and their actual effects were difficult to sort out. Bivariate examination was somewhat useful, as seen in the separation of length of exposure from latency (Figs 7 and 8).

The welders in Local 104 had had potential exposure to a variety of occupational and nonoccupational hazards. The fume created during welding, for example, commonly contained oxides of iron, zinc, lead, and chromium and the gases carbon monoxide, nitrogen dioxide, and ozone. Another potential occupational exposure was asbestos in shipyards, where most of the Local 104 welders worked at one time or another. In addition to the work-related hazards, there is evidence from several studies that welders may smoke cigarettes more than other occupational groups and the nation as a whole.[18 19 20] It has not been established whether this was true for Boilermakers Local 104 welders, however. While smoking could explain the lung cancer risk at Local 104, as noted in an earlier report,[7] emphysema — which is also caused by smoking — occurred at a normal rate (9 observed deaths versus 9.8 expected).

Internal comparison of welders and nonwelders in Local 104 also demonstrated a relatively high rate of lung cancer for welders: the attributable risk was 23.1 lung cancers per 100,000 welders per year, and again the excess risk was seen to the greatest extent 20 or more years after first exposure. If it is assumed that welders and nonwelders in Local 104 smoked cigarettes and encountered occupational exposures other than welding to an equal extent, then it appears that welding fume was a lung carcinogen with an effect above the background of cancer resulting from other exposures.

From these and other data it is clear that welders have a relatively high lung cancer risk. It is not as clear, however, that welding fume is the causative agent. Most of the studies to date have included shipyard welders in their study populations; thus, asbestos in shipyards may be partly responsible for the risk. Another question is the contribution of cigarette smoking. While internal comparisons in the present study indicate that welding fume may be causative, further study is recommended, especially of nonshipyard welding populations.

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