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Silicosis and lung cancer among Chinese granite workers

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CHIA S-E, CHIA K-S, PHOON W-H, LEE H-P. Silicosis and lung cancer among Chinese granite workers. *Scand J Work Environ Health* 1991;17:170-4. Of the 184 cases of silicosis registered between 1 January 1970 and 31 December 1984 in Singapore, all the relevant information was available for 159, which were linked to the population-based National Cancer Register for lung cancer. Nine cases of lung cancer were found. The standardized incidence ratio (SIR) was computed with the age- and calendar-specific incidence of lung cancer rates of Chinese males in Singapore as a basis. Excess risk of lung cancer was found (SIR 2.01, 95 % confidence interval 0.92-3.81). Adjustment for smoking showed that it alone could not account for the excess lung cancer risk. There was an increasing, but not significant, trend with increasing severity of silicosis and exposure duration. The results suggest that the severity of silicosis and possibly exposure to free silica may have contributed to the excess of lung cancer among the cases of silicosis studied.

Key terms: register, smoking, surface mining, standardized incidence ratio.

Some authors have recently reported an association between silicosis and lung cancer (1-3). However, most of their studies did not have data on smoking habits, which is a major confounder. Another difficulty in interpreting several of the available epidemiologic investigations on the relationship between silica exposure and lung cancer has been combined exposure with other known lung carcinogens, such as radon daughters (in underground mining), asbestos (from ship-building and repair and demolition work), and polycyclic aromatic hydrocarbons (in foundries and ceramics manufacturing). Only a few studies (4-6) have concentrated solely on exposure in the granite industry. Neither Davis et al (4) or Steenland & Beaumont (6), in their studies of granite workers and granite cutters, respectively, showed any significant association between silicosis and lung cancer.

In a recent editorial review (7) of the silicosis-lung cancer association, JC McDonald noted that most of the reported studies on silicosis were linked to compensation. Compensation depends largely on disability, which can be affected by smoking. The individual who qualifies as a "silicotic" would probably be a heavy chronic smoker. This relationship in itself rather than silica exposure as such would have contributed to a higher incidence of lung cancer among the persons compensated as silicotics than among the general population.

To date, all the reported studies have come from western countries. To our knowledge, there is only one report concerning silicosis and its association with lung cancer among the Chinese population (8).

In Singapore silicosis is a notifiable occupational disease (9) for which workers can receive compensation (10). All cases of suspected silicosis are investigated by the Department of Industrial Health, Ministry of Labour. Confirmed silicotics are registered in the Silicosis Register of the Department. This register is representative of all confirmed silicotics in Singapore. It is kept mainly for statistical purposes.

Generally, the register includes all workers diagnosed as silicotics according to their history of occupational exposure and the results of chest radiography. Only some of these men received compensation, as compensation requires evidence of definite respiratory impairment in lung function tests. The aim of this study was to examine the association between silicosis and lung cancer in this group of male Chinese silicotics, who had worked at surface granite quarries in Singapore.

Material and methods

Since 1969, the Department of Industrial Health has been keeping a register of all confirmed cases of silicosis in Singapore. Confirmation of the diagnosis is made mainly on the basis of the following findings: (i) a confirmed history of occupational exposure to dust containing free silica, (ii) a clinical picture consistent with the disease and exclusion of other similar diseases, and (iii) a chest radiograph consistent with silicosis.

The chest radiographs were read by an occupational physician and a consultant radiologist. The films were compared with the standard films of the International Labour Organisation (ILO) and graded according to

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the relevant ILO International Classification of Radiographs of Pneumoconiosis.

The study was confined to Chinese male silicotics as there were few cases among women. Other ethnic groups were excluded because of their small numbers. A total of 184 cases of silicosis received confirmation between 1 January 1970 and 31 December 1984. All the relevant information except the smoking history was available for each case. Only 159 cases had complete smoking histories. As the smoking status of the subjects was critical to the analysis of the data, the other 25 cases were excluded from the study. The participation rate was therefore 86.4 %.

All of the subjects were employed in granite excavation and crushing at the quarry face (all surface work). It is thus unlikely that these workers were exposed to radon daughters. In addition none of the workers had a history of work in underground mines (11). None of the men reported a history of exposure to asbestos. This information was confirmed by a check for the names of the subjects in the register kept by the Department of Industrial Health of workers with asbestos exposure. The work processes and exposure in this industry has been described in a previous paper (12). As these jobs were specific in nature, a possible concomitant exposure to polycyclic aromatic hydrocarbons could be excluded.

The subjects were generally from the older age group with a mean age of 63 (SD 10) years. The mean exposure duration was 24 years, ranging from 1 to 51 (SD 10) years. The particulars (name and/or national registration number) of the 159 cohort members were checked against the population-based Singapore Cancer Register for lung cancer. Nine cases of lung cancer (code 162 of the International Classification of Diseases, ninth revision) were revealed.

Because the reliability of the quantitative information on cigarette consumption was uncertain, a dichotomous classification (smoker, nonsmoker) was used. A smoker was defined as a person who had ever smoked more than 10 cigarettes per day for more than one year. Ex-smokers were also included in this category.

A modified life-table method was employed in which person-years of observation were accumulated for each exposed duration in five-year age groups and five-year calendar intervals. These data were then used to generate expected numbers of incident lung cancer cases on

the basis of age- and calendar-specific incidence rates for Chinese men in Singapore. The standardized incidence ratio (SIR) was computed as the ratio of the observed number of cases to the expected numbers of cases of lung cancer.

The statistical significance of the SIR values was determined under the assumption of a Poisson distribution for the observed number of lung cancer cases, as described by Bailar & Ederer (13). All the statistical computations were performed with the man-years FORTRAN program (14).

Results

Table 1 shows the basic characteristics of the study cohort. A total of nine cases of lung cancer was observed in the group as opposed to the expected three cases from the general population. The SIR for lung cancer in the group was 2.01 (95 % confidence interval 0.92–3.9).

When the subjects were grouped by latency period, no cases were observed for the period of <20 years. Most of the cases (N=6) occurred in the 20- to 40-year group with an SIR of 2.3 (table 2).

As shown in table 3, the risks for lung cancer appeared to be related to the number of years since first exposure to silica dust. There was a progressive increase in the SIR as the exposure duration increased. Although this trend was not statistically significant, there is an apparent numerical increase. The highest risk of lung cancer occurred after >40 years since first exposure. Smoking was not likely to have been respon-

Table 1. Basic characteristics of the subjects.

Characteristic	N	%
Total number of Chinese men	159	.
Person-years at risk	1666	.
Observed number of lung cancer cases	9	.
Expected number of lung cancer cases	3	.
Smokers		
Number	133	.
Percentage of total number of men	.	83.6
Nonsmokers		
Number	26	.
Percentage of total number of men	.	16.4

Table 2. Standardized incidence ratio (SIR) with its 95 % confidence interval (95 % CI) for lung cancer cases in the study population by latency period.

Latency period (years)	Person-years	Observed number of cases	Expected number of cases	SIR	95 % CI
<20	265.8	—	0.48	0	.
20–40	1146.9	6	2.65	2.26	0.83–4.92
>40	253.3	3	1.35	2.23	0.46–6.50
Total	1666.0	9	4.48	2.01	0.92–3.81

Table 3. Standardized incidence ratio (SIR) with its 95 % confidence interval (95 % CI) for lung cancer cases in the study population by exposure duration and smoking habits.

Exposure duration (years)	Person-years	Observed number of cases	Expected number of cases	SIR	95 % CI ^a	Smokers (%)
0–20	104.6	—	0.24	0	—	75
20–40	951.2	4	2.27	1.76	0.62–5.81	85.6
>40	610.2	5	1.97	2.54	0.64–4.60	83.0

^a The test of trend in the SIR values using the multinomial distribution was not significant (exact one-sided $P = 0.28$).

Table 4. Standardized incidence ratio (SIR) with its 95 % confidence interval (95 % CI) for lung cancer cases in the study population by radiographic classification and smoking habits.

Classification	Person-years	Observed number of cases	Expected number of cases	SIR	95 % CI ^a	Smokers (%)
Category 1	923.1	4	2.85	1.40	0.38–3.58	80.5
Category 2	485.0	3	1.08	2.79	0.58–8.16	92.0
Category 3	173.9	2	0.39	5.11	0.62–18.45	76.5

^a The test of trend in the SIR values using the multinomial distribution was not significant (exact one-sided $P = 0.097$).

Table 5. Standardized incidence ratio (SIR) with its 95 % confidence interval (95 % CI) for lung cancer cases in the study population by smoking category.

Smoking category	Person-years	Observed number of cases	Expected number of cases	SIR	95 % CI
Nonsmoker	252.5	1	0.77	1.30	0.03–7.22
Smoker	1413.5	8	3.71	2.16	0.93–4.25

sible, as the distribution of smokers among the groups was similar.

In addition, the SIR increased (from 1.4 to 5.11) as the profusion of opacities increased in the chest radiographs (category 1 to category 3). A test of trends in the SIR values was not significant. The percentage of smokers in categories 1 and 3 were fairly similar (table 4).

Of the men with lung cancer 88.9 % (8 of 9) smoked. Among the smokers there were eight observed cases as compared with an expected number of 3.71. There was only one nonsmoker with lung cancer, the SIR being 1.30 (table 5).

Discussion

One of the greatest drawbacks of our study was the size of its population. In an effort to remove all potential confounders and to focus on a very specific group of silicotics, we had to settle for a study population of 159 subjects. This small size alone could have accounted for some of the results being not statistically significant when the different variables (latency period, exposure duration, severity of silicosis) and its patterns were analyzed. However we did find some interesting trends which warrant discussion and further study.

Our results indicate that there is an excess number of lung cancer cases among male Chinese granite quarry workers who have received confirmation of silicosis when the general population is used for comparison. The SIR of 2.01 is higher than the value estimated for silicotic subjects in Italy (SIR 1.5) (15) and Canada (SIR 1.98) (1) but lower than the value determined in Finland (SIR 3.05) (3). However, it is very similar to the risk of 2.03 determined for Hong Kong silicotics (8). The comparison should be considered with care however since the silicotic populations of the other studies were obtained from compensation registers. The International Agency for Research on Cancer has cited several reasons why case studies based on a silicosis register may be biased towards a silicosis-lung cancer association (16). There are always the problems of the definition of compensational silicosis, possible differences in disease detection methods, probable differences in smoking prevalence, and confounding occupational exposures.

JC McDonald has questioned the use of silicosis registers based on compensation for studies as follows: "Compensation depends largely on disability and therefore on smoking . . . [p 290]" (7). Hessel et al (17) have also commented: "It is thought by many of those concerned in the awarding of compensation in South Africa that the disability documented in silicotic sub-

jects and other miners exposed to silica results more from cigarette smoking than from silicosis [p 9].” This statement may be true of other silicosis compensation registers also.

The silicotics of our study were obtained from a register kept for statistical purposes. Not all of the workers in the register had received compensation, as compensation was dependent on the severity of their respiratory functions. Therefore it was not likely that the subjects were included in the register as a result of their disability, which may be more influenced by smoking than by silica exposure.

The duration of exposure to silica dust appears to be a factor in the risk of our subjects’ development of lung cancer, as an increasing risk was noted with increasing exposure. This trend was not significant, probably due to the lack of power in our study as the numerical increases were very apparent. Ng et al (8) also reported that the risk of lung cancer death was related to the number of years worked. It was possible that the relationship between silica exposure and lung cancer could have been influenced also by other factors, for example, smoking or exposure to polycyclic aromatic hydrocarbons (PAH) from diesel machine emission. Of the nine men who had lung cancer, eight were smokers and one was a nonsmoker. Smoking alone may have accounted for most of the excess lung cancer. But the increased risk of lung cancer as exposure increased was probably not due totally to smoking, as the distribution of smokers was very similar across the groups. (See table 3.) As only a qualitative measure of smoking habits was used, one cannot be certain whether the quantitative smoking habits may actually differ within the groups. Thus smoking cannot be totally removed as a possible confounder in our study. Some of the subjects may have been exposed to exhaust fumes from the compressor machines used to run pneumatic tools for breaking granite slabs and drilling holes for dynamite. But since the work took place in an open quarry, it is doubtful that the exposure (to PAH) was significant.

There also appeared to be an association, though not significant, between the severity of silicosis and lung cancer excess in our study. Similar findings were also reported by Ng et al (8). Fibrosis is a characteristic feature of silicosis, and the categories of the silicotics’ chest radiographs could serve as an indirect means with which to assess the severity of the fibrosis. The lung cancer excess was greatest among the silicotics in category 3 (SIR 5.11). This finding would support the hypothesis that scarred lung tissue could serve as the seed for neoplastic changes (18–20).

One of the major weaknesses in some of the reported studies is the absence of smoking history among the cases or an inappropriate (based on smoking or the absence of this information) reference population. The proportion of smokers in the register was 83.6 %. This figure was higher than that for the same age group of the male population of Singapore (47.9 %) in 1984

(21). It would be ideal if a more complementary reference population had been chosen. But a more appropriate one, as in most situations, was not available. However, could the overrepresentation of smokers in this study totally account for the double risk of lung cancer?

Axelson’s (22) method was used to adjust the expected lung cancers for the differences in smoking habits in an effort to determine the smoking-adjusted risks of lung cancer in the cohort versus the reference population. A lung cancer risk factor of 20 was assumed for the smokers versus the nonsmokers. The calculation showed that a 67.5 % (95 % confidence interval 58.7–77.8) increased risk might be expected for the cohort because of the difference in smoking prevalence. This possibility implies that the excess lung cancer risk found in the study could not be entirely accounted for by smoking alone. Only one lung cancer case was a nonsmoker. Thus it was not possible to study the effects of silicosis and lung cancer among the nonsmokers. Perhaps, as more cases are collected over the years, it may be feasible to study this important association — minus the smoking factor. Such a study is conceivable as the confirmed silicotics are being followed every three years and their life status is being noted yearly through the National Registry of Births and Deaths in Singapore.

In conclusion, this study showed that there was an excess of lung cancer cases among the study cohort as compared with the general population. In view of the limited size of the study, caution is warranted in the drawing of conclusions. The results suggest, however, the possibility that the severity of silicosis and possibly exposure to free silica contributed to the excess of lung cancer among the cases of silicosis studied.

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