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Exposure-specific lung cancer risks in Chinese chrysotile textile workers and mining workers

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ABSTRACT

Objective: Whether there is a difference in the exposure–response slope for lung cancer between mining workers and textile workers exposed to chrysotile has not been well documented. This study was carried out to evaluate exposure-specific lung cancer risks in Chinese chrysotile textile workers and mining workers.
Subjects and methods: A chrysotile mining worker cohort and a chrysotile textile worker cohort were observed concurrently for 26 years. Information on workers' vital status, occupational history and smoking habits were collected, and causes and dates of deaths were verified from death registries. Individual cumulative fiber exposures were estimated based on periodic dust/fiber measurements from different workshops, job title and duration, and categorized into four levels (Q1–Q4). Standardized mortality ratios (SMRs) for lung cancer were calculated and stratified by industry and job title with reference of the national rates. Cox proportional hazard models were fit to estimate the exposure-specific lung cancer risks upon adjustment for age and smoking, in which an external control cohort consisting of industrial workers without asbestos exposure was used as reference group for both textile and mining workers.
Results: SMRs were almost consistent with exposure levels in terms of job titles and workshops. A clear exposure–response relationship between lung cancer mortality and exposure levels was observed in both cohorts. At low exposure levels (Q1 and Q2), textile workers displayed higher death risks of lung cancer than mining workers. However, similarly considerably high risks were observed at higher exposure levels, with hazard ratios of over 8 and 11 at Q3 and Q4, respectively, for both textile and mining workers, after both age and smoking were adjusted.
Conclusion: The chrysotile textile workers appeared to have a higher risk of lung cancer than the mining workers at a relatively low exposure level, but no difference was observed at a high exposure level, where both cohorts displayed a considerably high risk.

1. Introduction

The carcinogenicity of asbestos has been extensively documented, and accumulative evidence has shown that all types of asbestos are capable of causing lung cancer and other forms of cancer [1,2]. Toxicological review data also supported that all three commercial fiber types had produced a similar level of lung tumors in animal experiments [3]. However, some questions remain in debate regarding the risk discrepancy in different types of asbestos and in different asbestos industries. A meta-review by Lash et al. from 15 cohort studies found a substantial heterogeneity in the slopes for lung cancer and asbestos exposure, but no evidence in this meta-analysis can explain the difference of slope by fiber type [4]. Another review by Hodgson and Darnton also demonstrated the significant heterogeneity of lung cancer risk in chrysotile worker cohorts, particularly the great differences in the findings from chrysotile miners and textile workers [5]. Some researchers have proposed that carcinogenicity of chrysotile is far less than that of amphiboles. They claim that chrysotile can be used safely by properly controlling human exposure to it [6,7]. Others, however,

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suggest that chryostile is as carcinogenic as amphiboles, especially in the case of lung cancer [8–10]. Although most previous data were provided from western countries, there have been a few recent studies from China providing additional evidence for a strong association between chrysotile exposure and lung cancer in asbestos textile workers and asbestos mining workers [11,12].

Another issue that has not been well documented is the so-called "textile mystery", which described the higher incidence or mortality from lung cancer in asbestos textile plants than in asbestos mining and milling plants in western countries [13–17]. Different hypotheses were proposed to explain the cause of the "textile mystery" [17–20], but none of them has, as yet, been convincing. There has been no such data from an Asian country to document the issue, partly because quantitative exposure data were seldom available. We previously reported two cohorts of asbestos exposed workers in China, one from a chrysotile mine [12], and the other from a chrysotile textile factory [11], from both of which we observed significantly excess mortality from lung cancer. We have carried out a further analysis with the available data, aiming to estimate the exposure-specific risks of lung cancer in the asbestos textile and mining workers.

2. Subjects and methods

2.1. Study cohorts

The details of the two cohorts were described previously [11,12]. In brief, the original textile cohort from an asbestos product factory in Chongqing, consisting of 586 male workers who were employed for minimum one year at entry was followed from January 1, 1972 to December 31, 2008. The mining worker cohort from the largest chrysotile mine in the country, located in Qinghai Province, comprising 1539 male workers who had also been employed at least one year at entry was followed from January 1, 1981 to December 31, 2006 [12]. To make the observation period consistent and comparable, we matched the textile worker cohort with the miner cohort in terms of a same observation period, i.e. from January 1, 1981 to December 31, 2006. To do so, we excluded those who died and retired before January 1, 1981 ($n = 113$) and lost to follow-up ($n = 9$) in the textile worker cohort, and made December 31, 2006 be the ending point of the observation, leaving 464 workers in the textile worker cohort (*textile workers*), along with 1539 workers in the miner cohort (*mining workers*) over the concurrent 26 year observation. No workers in the mine cohort were lost to follow during the observation period, largely due to a complete record kept by the asbestos mine administration.

2.2. Data collection

The study was approved by the Research Ethics Committee of the Chinese University of Hong Kong. As described previously [11,12], we collected data of vital status year by year using a combination of active follow-up and record links to death certificates. The date and underlying causes of death were retrieved from hospitals and death registries. We used a structured questionnaire to collect relevant data. Information on workers' detailed occupational history was mainly obtained from personnel or administrative departments of the factory and mine, which had kept good records. Individual smoking habits were obtained from a personal interview of those who were alive. For the deceased, the interview was administered in their spouses or next of kin.

2.3. Individual exposure assessment

Periodically measurements of asbestos dust concentrations in different workshops/departments were available in the asbestos factory and mine during the 1980s and the early 2000s. Almost no fiber data were available in China, because a national standard for asbestos fibers did not exist until 2002. In 2002, we collected simultaneously air samples and personal samples in the asbestos factory and measured fibers from the samples. Results showed that the fiber concentration was high in the raw material and textile sections, and low in the rubber board section [11]. This was consistent with previously measured dust and fiber concentrations in the factory [21]. In 2006, we measured the dust concentrations of eight workshops in the asbestos mine [12]. Based on a conservative estimate made by converting dust (mg/m^3) to fiber (f/ml) [22,23], an average fiber concentration was 29.0 f/ml, far exceeding the currently applied occupational exposure limit of 0.8 f/ml.

To evaluate the exposure-specific lung cancer risks, we estimated the cumulative fiber exposures for individual workers, using all available dust and fiber data from different times and different workshops. We used previously suggested approaches to convert the dust concentrations to fiber concentrations in both asbestos textile factory and asbestos mine [24,25]. In the asbestos textile factory, we used 120 paired fiber/dust samples from different departments collected in 1999 and 2002 to develop a linear regression equation to convert the dust concentrations into fiber concentrations [26]. The conversion data in the textile workers were log transformed, because the distribution of paired data was positively skewed, but this was not the case in the mining workers. The conversion equation was following: Ln (fiber concentration) = 0.354 + Ln (dust concentration), with a correlation coefficient of 0.596 between natural logarithms of fiber and dust concentrations. For the exposure assessment of asbestos mine, we first used paired samples with simultaneous gravimetric and membrane filter methods in the main workshops to develop a linear regression equation for the relationship between the dust and fiber concentrations: "Fiber concentration (f/ml) = (dust concentration (mg/m^3) + 1.0945)/3.2935", with a correlation coefficient of 0.88 between the dust concentration and fiber concentration ($p < 0.001$) [23]. We then used the equation to calculate the average airborne fiber concentrations related to individual workshops and specific jobs. The time period of individual exposures was defined as time since the first exposure until the end of follow-up (December 31, 2006) for active workers or until the date of last exposure for those retired or deceased. Furthermore, we made individual cumulative exposure estimates, expressed in fiber-years/ml (f-y/ml), as the product of estimated fiber concentrations in a specific workshop and job, and the duration of employment in each specific job. In the textile factory, historical measurements from all workshops have been available since 1955, which we used to estimate the exposures before 1955 for those who were hired earlier than 1955. During the period of 1955 and 1981, periodical data in every 5 years were available, which we used to calculate cumulative exposures of that period. In the asbestos mine, the earliest measurement data were collected in 1984, which we used to estimate the exposures before 1981 for those whose hiring dates were earlier than 1981. The calculation and assignment of the cumulative exposures were blinded to workers' vital status in both cohorts.

2.4. Data analysis

The data analysis mainly focused on the death risk for lung cancer at different exposure levels in the textile workers and mining workers. The calculation of person years at risk for each of the cohort members began from the start of follow-up (January 1, 1981) to the end of follow-up (December 31, 2006) or the date of loss to follow-up, or the date of death for the deceased, whichever occurred first. We first calculated standardized mortality ratios (SMRs) for lung cancer and stratified SMRs by different workshops and specific jobs the workers last undertook in the two cohorts.