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Letter to the editor

Occupational exposure to carbon black and risk of cancer

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Abstract

Objectives: To investigate cancer risk in dockyard workers exposed to carbon black.
Methods: Cancer incidence was ascertained among 2101 longshoremen employed at the dockyard of Genova, Italy They were categorized *a priori* as exposed to low, moderate, and high level of carbon black dust. Incidence rates for the male population of the City of Genova were used to compute standardized incidence ratios (SIR).
Results: A positive exposure–response relation with carbon black exposure was detected only for bladder cancer (SIR = 204, 95%CI = 112–343, in highly exposed workers). Increased incidence of pleural mesothelioma (SIR = 751, 95%CI = 302–1547) and melanoma (SIR = 288, 95%CI = 125–2168) were detected.
Conclusion: Exposure to carbon black experinced by dockyard workers was associated with a two-fold increased risk of bladder cancer.

Introduction

Carbon black is a powdered form of elemental carbon manufactured by controlled pyrolysis of hydrocarbon mixtures, such as heavy petroleum distillates and residual oils, coal-tar products, natural gas and acetylene. Sometimes confused with soot, carbon black is a very different material. While carbon black is produced under controlled and exacting conditions, resulting in well-defined carbon particles, soots are a generic collection of undefined substances produced by or pyrolysed from fuels during uncontrolled combustion. The carbon particles in soots contain very high percentage of loosely retained tarry material that, in turn, contains large amounts of polycyclic aromatic hydrocarbons (PAH). In contrast, the well-defined carbon particles in carbon black have been found to contain between 0.02 and 0.20% solvent-extractable material, of which PAH constitute only a small portion.

Carbon black is primarily used as a reinforcing agent in rubber products, mainly tires and other automotive products, gaskets and coated fabrics. Carbon black is also used as a black pigment in inks, toner and paints, in plastics, and in the manufacture of dry-cell batteries. Epidemiology studies of workers in the carbon black producing industries of North America and Western Europe were linked to an increased risk of cancer of the lung, bladder, kidney, oesophagus, and skin [1–6]. Other studies indicated not significant excess of risk or no excess [7–11].

In 1996 the International Agency for Research on Cancer (IARC) reevaluated carbon black as a group 2B (possible human carcinogen) based on the development of lung tumors in rats receiving chronic inhalation exposure to free carbon black [12].

We report an historical cohort study among longshoremen at the dockyard of Genova, Italy, in order to investigate occupational cancer risk. From 1990 to 1999, some longshoremen with bladder cancers filed a claim to the National Italian Institute of Insurance against

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Accidents at Work (Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro, INAIL). Between 1947 and 1960, these men unloaded carbon black paper sacks at the dockyard. The study was conducted to investigate whether there was any association between occupational exposure to carbon black and the occurrence of site specific cancers, including cancer of the bladder.

Subjects and methods

Our study included the 2286 longshoremen employed at three dockyard companies in Genova, Italy between 1 January, 1933 and 1 January, 1980. They were categorized *a prior* into three subgroups with varying levels of exposure to carbon black. Exposure classification was done according to each worker lifetime occupational history as recorded in the employees register obtained from the Genova Dockyard Authority. Occupational history included date of hire and cessation in each of the three dockyard companies. Employees historical data showed that most longshoremen (96%) worked for the same company during their occupation at the dockyard. Those unloading occasionally (n = 919) and frequently (n = 771) carbon black pallets from the ships to the piers by forklift trucks and cranes (*i.e.*, mechanical unloading), were classified as exposed to low and moderate levels of carbon black, respectively. Longshoremen who carried carbon black paper sacks on their shoulders (n = 596) were classified as exposed to high levels of carbon black. Between 1947 and 1957, 8000–12,000 tons of carbon black were unloaded per year. Since 1958, the quantity of carbon black unloaded decreased sharply to a few thousand tons per year. Sealed boxes replaced paper sacks in 1960, reducing further the potential for occupational exposure to carbon black. For these reasons, statistical comparisons were performed also according to year of hire using 1958 as a cut-off date.

The follow-up period ranged between 1 January, 1986 and 1 January, 1996. The vital status of each man was ascertained from the demographic registry of his place of residence until 31 December, 1996. Sixteen workers (0.7%) emigrated and 169 (7.4%) died before the starting date of follow-up and therefore they were excluded from the linkage procedure, leaving 2101 dockyard workers eligible for statistical analysis. Accordingly, 858, 709, and 534 were identified as exposed to low, moderate, and high levels of carbon black, respectively. Cancer incidence was established by record linkage with the Genova cancer registry for 1986–1996 (the interval for which data are available). Standardized incidence ratios (SIRs) were calculated as the ratio of the number of site-specific cancer cases observed in the study cohort to those expected. Expected cases were calculated by applying five year age- and site-specific cancer incidence rates for the male population of the City of Genova to the person-years of observation accumulated for the whole cohort and in each identified subgroup of exposure to carbon black. We calculated two-sided 95% CIs for the SIRs on the assumption of a Poisson distribution of the observed cases. Statistical calculations were performed by using STATA® statistical package [13].

Results

Person-years of observation by level of exposure and year of hire are reported in Table 1. Mean age at hire at the dockyard was 21.5 years (SD = 4.6), mean age at entry into follow-up was 52.6 years (SD = 7.7), and mean age at end of follow-up was 61.5 years (SD = 7.6). There were 208 incident cases in the study cohort across the period of follow-up, 16 (7.7%) of which were diagnosed within 29 years since first employment at the dockyard and 192 (92.3%) after 30 years since hire (data not shown). Fifty-two out of 53 cases of lung cancer, 6/7 pleural mesothelioma, 8/8 cases of melanoma, and 30/32 cases of bladder cancer were detected after 29 years since first hire at the dockyard (data not shown). Standardized incidence ratios (SIRs) for specific cancer sites detected in the whole cohort of dockyard workers are shown in Table 2. Although the incidence for all cancers was slightly lower than expected (SIR = 95, 95%CI = 83–109), significantly increased SIRs were observed for pleural mesotheliomas (SIR = 751, 95% CI = 302–1547) and melanoma (SIR = 288, 95% CI = 125–568). Less markedly increased SIRs were detected for cancer of the tongue (SIR = 121, 95%CI = 15–437), oesophagus (SIR = 162, 95%CI = 44–415), liver (SIR = 124, 95%CI = 57-235), larynx (SIR = 154, 95%CI = 84–258), bladder (SIR = 130, 95%CI = 89–184), thyroid (SIR = 232, 95%CI = 28–836), non-Hodgkin lymphoma (SIR = 120, 95%CI = 48–247), and myeloma (SIR = 136, 95%CI = 28–398). Lung cancer incidence was not increased (SIR = 108, 95%CI = 81–141). Lower than expected SIRs were observed for cancer of the stomach (SIR = 29, 95%CI = 6–85), colon and rectum (SIR = 89, 95%CI = 56–135), pancreas (SIR = 22, 95%CI = 22–210), skin (other than melanoma, SIR = 66, 95%CI = 36–110), prostate (SIR = 56, 95%CI = 22–115), kidney (SIR = 67, 95% CI = 22–157), and other cancers (SIR = 40, 95%CI = 21–69).

SIR analysis by levels of exposure to carbon black dusts (Table 3), revealed negative, not statistically significant, (p trend = 0.35), exposure-response relations for pleural mesothelioma and melanoma (p trend = 0.47). A ten-fold increased incidence (SIR = 1044, 95%CI = 284–2672) was observed for pleural mesothelioma in the group with low exposure to carbon black. Bladder cancer incidence peaked in workers with high exposure to carbon black dusts (SIR = 197, 95%CI = 108–330) and non-Hodgkin lymphoma in subjects with moderate exposure to carbon black (SIR = 323, 95%CI = 119–704).

Table 4 reports SIRs for selected cancers by period of hire at the dockyard (< 1958, ≥1958). Significantly increased SIRs were detected among dockyard workers hired before 1958 for pleural mesothelioma (SIR = 530, 95%CI = 144–1356), melanoma (SIR = 355, 95%CI = 130–772)., for and by levels of exposure to carbon black dusts. The incidence of pleural mesothelioma was markedly increased also among workers hired ≥1958 (SIR = 1691, 95%CI = 349–4942). SIRs for selected cancers by period of hire at the dockyard (<1958, ≥1958) and by level of exposure to carbon black are shown in Table 5. Incidence of pleural mesothelioma was increased for all levels of exposure to carbon black both in workers hired before and after 1958. SIR for pleural mesothelioma peaked in workers hired ≥1958 and exposed to low levels of carbon black (SIR = 2510, 95%CI = 304–9066). Increased SIRs for melanoma, were common to almost all groups of exposure to carbon black in workers hired before 1958. The highest SIR was observed in workers hired < 1958 and with moderate exposure to carbon black (SIR = 740, 95%CI = 53–2163). Bladder cancer incidence was increased in dockyard workers hired before 1958 and highly exposed to carbon black dusts (SIR = 204, 95%CI = 112–343). Among workers hired before 1958 bladder cancer incidence increased, although not significantly (p trend = 0.09), with increasing level of exposure to carbon black. The excess of non-Hodgkin lymphoma was entirely confined to workers hired before 1958 and exposed to a moderate level of carbon black (SIR = 426, 95%CI = 138–995).

Discussion

The present study was aimed at investigating whether there was any association between cancer occurrence and exposure to carbon black experienced by 2101 longshoremen employed at the dockyard of Genova, Italy between 1933 and 1980. Cancer incidence in the study cohort was ascertained by record linkage with the Genova Cancer Registry for the follow-up period 1986–1996. A limit of the record-linkage procedure is that while it assures that all the identified cancer cases are true cancers, it does not guarantee that the workers not found (*i.e.*, linked) in the cancer registry database are true non-cancers. They may have not been identified as cancer cases simply because of differences in the demographic data (*i.e.*, last and first name and date of birth). The limited sensibility of the linkage procedure is likely to have lead to a conservative estimation of the computed SIRs. Another limitation of this study concerns the definition of the follow-up that was restricted, necessarily, to the time interval 1986–1996 for which cancer incidence data were available. Workers who died before or migrated before 1986 were excluded from the linkage procedure and this may have resulted in a dilution of the risk of cancer estimated by this study due to both competing mortality and healthy worker effect, the latter acting mainly in its exposure-related susceptible-worker survivor component effect [14], resulting in differential survival of workers with different risks of disease [15]. In spite of its conservative nature, the study detected an increased incidence of site specific cancers among longshoremen employed at the dockyard. Decreased SIRs were detected for all cancers, cancer of the stomach, skin, prostate and kidney. The seven-fold and three-fold increased SIR observed for pleural mesothelioma and melanoma were not found to be associated with the level of exposure to carbon black dusts experienced by longshoremen during their working activity at the dockyard. The higher SIRs were observed in workers with low and/or moderate exposure to carbon black. Therefore, the excess incidence of pleural mesothelioma is likely to be linked with relevant and ubiquitous exposures to asbestos fibers that have been repeatedly reported by occupational studies [16]. The increased incidence of melanoma revealed by the study may be associated with working practices performed outdoor (at the piers) that allowed a high degree of exposure to sunlight. The epidemiologic literature reports associations between melanoma and sun light exposure [17], radiation exposure [18–19, 23–24], occupational exposures to volatile chemicals typically found in the printing industry [20–22], and exposures to solvents experienced by chemists in some laboratories [23, 24]. Therefore the excess incidence of melanoma that was observed in our cohort may be related both to exposure to sunlight and chemical agents, including carbon black through a possible synergic effect.

The results of our study are suggestive of an association between exposure to carbon black dusts and bladder cancer development, as previously reported [25]. The increased SIR for bladder cancer detected in the

entire cohort (SIR = 130, 95%CI = 89–184) was confined among dockyard workers with a high level of exposure to carbon black dusts (SIR = 204, 95%CI = 112–143) who were hired before 1958. Before this year, workers employed at the dockyard of Genova were used to carry carbon black paper sacks on their shoulders. The substantially reduced incidence of bladder cancer detected among workers first employed after 1958 (SIR = 95, 95%CI = 26–243), when paper sacks containing carbon black were replaced with sealed boxes, is likely to reflect improvements introduced in the working conditions and the reduction of the amount of unloaded carbon blacks. Lung cancer incidence was close to the expected (SIR = 108, 95%CI = 81–141) thus excluding smoking as a potential confounding factor for the increase incidence of bladder cancer. Therefore, the observed increase of bladder cancer detected in dockyard workers may be linked to relevant exposures to carbon black dusts experienced at the dockyard of Genova during manual unloading of paper sacs. Since dockyard workers who carried carbon black paper sacs on their shoulders were considered highly exposed, the study findings suggest that absorption through the skin may have played a main role in the uptake carbon black.

Our results support the findings of a previous study conducted among male workers employed in the carbon black production industry in the UK [1], where carbon black was the prevalent exposure (RR = 2.5, 95%CI = 0.5–7.3) and in the male population of Montreal [3] with any known exposure to carbon black dusts (RR = 1.2, 95%CI = 0.7–1.9). A recent study [26] reported the highest DNA levels in urothelial cells of workers engaged in the rubber mixing and curing processes when compared to workers from other production areas.

In conclusion our results confirm previous findings indicating that exposure to carbon black is associated with an increased risk of bladder cancer in humans.

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