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LUNG CANCER AND MESOTHELIOMA AMONG ENGINE ROOM CREW - CASE REPORTS WITH RISK ASSESSMENT OF PREVIOUS AND ONGOING EXPOSURE TO CARCINOGENS

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ABSTRACT

Objective The aim of this article is to illustrate, by means of case reports on occupational exposure in four men with cancer, the hazards of previous and ongoing carcinogenic exposures in ships' engine rooms. Several cases of cancer occurred within a few years among the engine room crew of a passenger ferry. An investigation was undertaken to establish the number of cases, the types of cancers involved, and their possible relation to work.

Subjects and Methods Nine cases of cancer among crew members of the ferry were reported between 2001 and 2006, six of which occurred in crew working in the engine room. During the investigated time period, 65 men had been employed in the engine room (mean age 40, range 16–65, years). Four cases were referred to our department. Medical history, personal risk factors and specific diagnoses were collected by medical examinations and from the medical files. An experienced occupational hygienist evaluated work-related exposure to carcinogens.

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Results Two engine room ratings contracted lung cancer at the age of 54 and 61, respectively. Both men had been smokers for many years (33 and 45 years, respectively). One engine room rating and one electrical engineer were diagnosed with mesothelioma at the age of 61 and 63, respectively. All four had started to work in engine rooms between 1959 and 1967. Carcinogenic exposure included asbestos, with an estimated cumulative exposure of 2–5 fibreyears/mL, as well as polycyclic aromatic hydrocarbons (PAHs) and nitroarenes from oils, soot and engine exhaust.

Conclusions For the lung cancer cases, smoking and asbestos exposure were considered clear risk factors, and PAHs and nitroarenes possible risk factors. For the mesothelioma cases, former asbestos exposure was considered a causal factor. Asbestos can still be present on ships. Steps should be taken to reduce the exposure to asbestos, PAHs and nitroarenes, and smoking.

INTRODUCTION

In the autumn of 2005, an occupational health physician contracted by a major vessel company contacted our department. Several seafarers aboard a single passenger ship had contracted cancer within a brief time period, causing worry among the crew.

Excess incidences of lung cancer and mesothelioma have previously been reported among engine room crews (1-6). Asbestos is considered a relevant carcinogenic exposure in both these cancer forms (2, 7-9). Since the latency periods are very long for asbestos-related cancer (10 to 30 years for lung cancer and 30 to 50 years for mesothelioma), knowledge of previous or present asbestos exposure is an important factor in the risk assessment of cancer (7, 10-15).

Polycyclic aromatic hydrocarbons (PAHs) and nitroarenes, present in soot, oils and engine exhaust, constitute a daily exposure in machine rooms. PAHs have been linked to cancer in both animal and human studies (16-21). Metabolites of certain PAHs have also been shown to cause damage to deoxyribonucleic acid (DNA), which explains, at least in part, their cancerogenic effect (22).

The main aims of this article are to report the results of our investigations of four cases referred to our department and to discuss previous and ongoing exposure to carcinogens in the engine room on ships.

SUBJECTS AND METHODS

Subjects Nine cases of cancer were identified among the ship's crew members between 2001 and 2006. Six of these crew members worked in the engine room and four of them, two with lung cancer and two with mesothelioma, were referred to us for evaluation of work-related risk factors for cancer. A total work force of 65 men, mean age 40 (range 16–65) years in 2001, were employed in the machine room during the investigated time period. The other cases, one myeloma case, one thyroid cancer and three colon cancers, were not referred.

Methods Personal risk factors for cancer, such as smoking habits, hereditary factors or concurrent diseases, as well as type of cancer and year of diagnosis were collected for each patient by medical examination and medical files. All data were collected with informed consent from the patient or, if deceased, from the nearest relative. Information on position and time at sea as well as the name and type of vessels involved was gathered from the Swedish Maritime Administration, which keeps a service registry of all Swedish seafarers, the Swedish Registry of Seamen.

An experienced occupational hygienist estimated the exposures to carcinogenic substances in the work environment throughout the subjects' whole working career, based on interviews, data from the Swedish Registry of Seamen, and earlier research performed by us in machine rooms of similar vessels (23-25). The cumulative exposure to asbestos was estimated as fibreyears per mL, where 1 fibreyear/mL equals an exposure to one asbestos fibre per milliliter (mL) air during one year. The Swedish occupational exposure limit for asbestos is 0.1 fibre/mL during an 8-hour workday.

After a thorough search and compilation of current knowledge in the field, followed by a discussion in a clinical seminar, a risk assessment of previous and ongoing carcinogenic exposure was made for each cancer form involved.

RESULTS

Exposure The cumulative lifetime exposures to asbestos, with consideration of protective measures, were estimated to be 2–5 fibreyears/mL for all four investigated seafarers. Exposure to asbestos was considered to have been highest between 1960 and 1980 during repair work, which had involved elimination of asbestos insulation of exhaust and steam pipes or electrical wires. A constant low level of asbestos had probably been present in the air in the engine room during those years. Exposure to asbestos has then decreased continuously since 1976. Measurements of asbestos in 2003

on board similar vessels showed barely detectable amounts (localized to the upper boiler room and the funnel shaft). The asbestos found was amosite, but earlier investigations had also shown presence of crocidolite (23, 24) (and personal communication by Lars Sandberg, Göteborg)

There was daily exposure to polycyclic aromatic hydrocarbons and nitroarenes (through oils on hands, for instance). Exposure to PAHs and nitroarenes was especially high during major work on the main engine, for instance when entering the crankcase during overhaul operations, with resulting high exposures to lubricant oils and aerosols. Similar exposures occurred during work on auxiliary engines. Sweeping the sound absorbers led to high exposures to soot and, therefore, to PAHs. Testing the fuel injectors resulted in high exposure to aerosols from diesel oil (marine diesel may contain up to 25% PAHs).

Case studies The four cancer cases investigated were all Swedish men and had been working in engine rooms for over 40 years, Table 1. All were 50-60 years old when they contracted their cancer. The two cases with lung cancer had both been smokers for many years.

Table I. Cancer cases. Four out of nine seafarers with cancer on one ferry between 2001 and 2006. Cancer forms and relevant exposures are shown.

Cases	Age at diagnosis	Position	Total months at sea	Year signed on with ships	Smoker	Diagnosis	Year of diagnosis	Exposure
1	61 yrs	engine room rating, repairman	193	1962	45 yrs	Lung cancer	2005	Asbestos, 2 fibreyears/mL. PAHs, nitroarenes
2	54 yrs	engine room rating, repairman, pumpman	214	1967	33 yrs	Lung cancer	2005	Asbestos, 5 fibreyears/mL. PAHs, nitroarenes.
3	61 yrs	engine room rating	105	1959	no	malignant mesothelioma	2004	Asbestos, 2–5 fibreyears/mL
4	63 yrs	electrical engineer	175	1960	no	malignant mesothelioma	2001	Asbestos, 2–5 fibreyears/mL

DISCUSSION

Lung cancer For the two cases of lung cancer, both smoking and work-related exposure to asbestos were considered risk factors. Tobacco smoking increases the risk of lung cancer by up to 20 times, but the risk diminishes gradually upon quitting (26, 27). Asbestos is a well-known risk factor for lung cancer (7, 14). In insurance cases in Sweden, a period of 15–20 years in a clearly asbestos-exposed occupation is considered sufficient for workers' compensation for lung cancer (13). However, more recent data indicate elevated risks even at lower doses of asbestos exposure (28). Tobacco smoking interacts with asbestos exposure, increasing the risk of lung cancer even further (7, 13, 14, 28, 29).

Polycyclic aromatic hydrocarbons and nitroarenes may represent contributing risk factors for lung cancer, but the risk assessment is still very rudimentary (16-21). In some industries with PAH exposure, levels are generally much higher. Typical levels of urinary 1-hydroxypyrene (1-OHP, an indirect marker of PAH exposure) range from 1 to 25 µmol/mol creatinine (30). In engine room crew members, levels of urinary 1-OHP of 0.003 – 1.35 nmol/mol creatinine have been found (24). The levels were comparable to values among car repair workers and generally higher than the contribution from smoking (2). Different combinations of different PAHs may partly explain this phenomenon, since 1-OHP is a metabolite of only one PAH, namely pyrene. The project also revealed a significant increase in urinary 1-OHP during work shifts in the engine room and, importantly, lower levels with the use of protective measures (24, 25). A definite link between levels of 1-OHP in urine and risk of cancer has not yet been established (30). However, signs of oxidative damage to DNA have previously been demonstrated in engine room crew members exposed to PAHs, suggesting a cancerogenic effect from these compounds (31). Compared to tobacco smoking, the risk is probably smaller.

Mesothelioma Previous exposure to asbestos was considered a causal factor for the two cases with mesothelioma in the present study. The exact dose-response relationship is not known, but a few months up to a year of asbestos exposure is generally considered sufficient (32). Smoking is not a risk factor for mesothelioma (13). In the two men, asbestos exposure had occurred mainly in the 1960s and 1970s.

Owing to long latency periods, an elevated risk of cancer remains well after reduced asbestos exposure. Sweden was one of the first European countries instigating an asbestos ban, in 1976, and the incidence of mesothelioma, rising continuously since the 1970s, is now reaching a plateau (12, 33). In other countries, however, the ban occurred

much later (e.g. in the UK in 1985 and in France in 1996). Also, asbestos may still be used in foreign shipyards (10).

Other forms of cancer All cases of cancer could not be investigated (i.e. three colon cancers, one myeloma and one thyroid cancer). In a 1971–1987 survey of cancer in all Swedish seafarers, these cancer forms were not more common than in a general population (2). Some studies have suggested a carcinogenic role of asbestos in colon cancer (34-38).

CONCLUSIONS

Asbestos has been used extensively in engine rooms on ships and the exposure is a clear risk factor for lung cancer and mesothelioma. Since latency periods could be long, exposure far back in time must be considered. Asbestos use has been banned in shipyards in e.g. the Nordic countries, but could still be found in older ships and ships built in other countries. Ongoing exposure to PAH and nitroarenes from engine exhaust, soot and oils may represent a carcinogenic risk factor. Engine room crews should receive information, and safety measures should be implemented to reduce the exposure to these carcinogens. In addition smoking should be reduced.

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