Asbestos-Related Cancers Among 28,300 Military Servicemen in the Royal Norwegian Navy

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Introduction *This study focus on the incidence of asbestos-related cancers among 28,300 officers and enlisted servicemen in the Royal Norwegian Navy. Until 1987, asbestos aboard the vessels potentially caused exposure to 11,500 crew members.*

Methods *Standardized incidence ratios (SIR) were calculated for malignant mesothelioma, lung cancer, and laryngeal, pharyngeal, stomach, and colorectal cancers according to service aboard between 1950 and 1987 and in other Navy personnel.*

Results *Increased risk of mesothelioma was seen among engine room crews, with SIRs of 6.23 (95% CI = 2.51–12.8) and 6.49 (95% CI = 2.11–15.1) for personnel who served less than 2 years and those with longer service, respectively. Lung cancer was nearly 20% higher than expected among both engine crews and non-engine crews. An excess of colorectal cancer bordering on statistical significance was seen among non-engine crews (SIR = 1.14; 95% CI = 0.98–1.32). Land-based personnel and personnel who served aboard after 1987 had lower lung cancer incidence than expected (SIR = 0.77; 95% CI = 0.64–0.92). No elevated risk of laryngeal, pharyngeal, or stomach cancers was seen.*

Conclusion *The overall increase (65%) in mesotheliomas among military Navy servicemen was confined to marine engine crews only. The mesothelioma incidence can be taken as an indicator of the presence or absence of asbestos exposure, but it offered no consistent explanation to the variation in incidence of other asbestos-related cancers.* Am. J. Ind. Med. 53:64–71, 2010. *© 2009 Wiley-Liss, Inc.*

KEY WORDS: asbestos; mesothelioma; lung cancer; military personnel; vessel; engine room crew; cohort study

BACKGROUND

Since the early 1990s there have been allegations of exposures and health problems amongst Norwegian Navy personnel. Examples of media issues were congenital anomalies in children whose fathers had served aboard a missile torpedo boat, deaths among former submarine officers, chemical exposures at a Navy fire-fighting training facility, exposures from radar equipment, asbestos exposure aboard vessels and at naval shipyards, and cancer incidence at coastal forts in northern Norway. In 2001, the Navy started a joint venture project engaging the Cancer Registry of Norway to perform cancer incidence and mortality studies. In this article, we want to focus on potentially asbestos-related cancers among officers and enlisted men in the Navy, hereunder the Fleet, the Coast Guard, and the Coastal Artillery.

INTRODUCTION

The aim of the study was to evaluate the risk of asbestos-related cancers, with special attention towards those who

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served aboard Navy vessels during 1950–1987. In general, asbestos has been used in shipbuilding since 1880s [Harries, 1971], and in Norway for industrial purposes since around 1910. According to Statistics Norway, import to Norway increased sharply after WWII to 7,000 t in 1960, and peaked with 8,000 t in 1970. The bulk was used in asbestos–cement production and for insulation in ships and industry [Ulvestad et al., 2003]. More than 90% of the asbestos used for insulation was crysotile (white asbestos) belonging to the serpentine group, but also amphibole species like crocidolite (blue asbestos) have been used [Ulvestad et al., 2003, 2004]. Restrictions on use of asbestos were introduced gradually in Norway. In 1978, a regulation banned the use of asbestos if alternative materials were available. Restriction on use aboard ships was introduced the same year. The import declined to 2,300 t in 1977 and 100 t in 1980 and was finally prohibited in 1986.

Several types of cancer have been linked to asbestos exposure. The association with lung cancer and pleural and peritoneal mesotheliomas is well established and was first demonstrated by Doll [1955], Wagner et al. [1960], and Selikoff et al. [1964]. The association with excess gastrointestinal cancers was first shown in the Selikoff et al. [1964] study, and in 2005, indications were found in a study among Norwegian lighthouse keepers [Kjaerheim et al., 2005]. Laryngeal cancer is linked to asbestos in several studies [Stell and McGill, 1973; Raffn et al., 1989; Gustavsson et al., 1998; and others]. According to evaluations by the International Agency for Research on Cancer (IARC) [1998], excess cancers of the GI tract and the larynx followed exposure to different asbestos species, although not consistently. Recently, the evidence for causal associations between asbestos exposure and selected cancers was reviewed by a multidisciplinary committee appointed by the Institute of Medicine, U.S. National Academy of Sciences. Sufficient evidence was found for laryngeal cancer, while suggestive evidence only was found for pharyngeal, stomach, and colorectal cancers [Board on Population Health and Public Health Practices, 2006]. These conclusions were supported by a recent IARC working group [Straif et al., 2009]. We limited our study to cancers with sufficient or suggestive evidence.

Asbestos was applied aboard civilian and military vessels for heat and sound insulation, and for fireproofing. It was sprayed onto deck heads and bulkheads, while pipes and machinery were insulated with molded sections containing asbestos [Harries, 1971]. The operative Norwegian navy vessels during the 1950s and early 1960s were built before and during WWII with asbestos applied in rooms and on installations inside as well as outside the engine rooms in a manner that potentially could put the entire crew at some risk. During the early 1960s, most of the Fleet was renewed [Pettersen, 1990] but asbestos was still applied in the same manner. Most insulation aboard contained asbestos, including that of the hull [Børresen et al., 2007]. It has been hypothesized that vibrations during sailing and gunnery practice would release asbestos fibers to the breathing atmosphere in most areas aboard. In submarines, active handling of asbestos was largely limited to the engine rooms, but the closed environment during submerged might have put all submariners at risk. Additional to the building procedure, operations such as inspections, maintenance, repair, and refitting would involve contact with asbestos.

Several studies on asbestos-related cancers have been performed internationally among personnel from civilian vessels. Nordic seafarers on merchant vessels had an overall increased risk of pleural cancer [Andersen et al., 1999], and Saarni et al. [2002] found significant excess of both lung cancers and mesotheliomas among Finnish engine room crews. To our knowledge, no such study has been performed among crews aboard military vessels. Navy vessels, especially warships, may differ from civilian ships, by having more powerful engines and target practice. Measurements of suspended asbestos fibers were conducted on a Royal Navy frigate in 1987. Low levels of amosite (brown asbestos) were detected in the boiler room and the storeroom alow during gunnery practice [Moen et al., 2005], supporting the idea of vibration and fiber release.

MATERIALS AND METHODS

Study Population

A historical cohort of 28,345 commissioned and non-commissioned officers and enlisted servicemen who served in the Royal Norwegian Navy between 1950 and 2004 has been established. Women were not included due to small numbers (719). Conscripts in compulsory service that did not achieve an officer's rank were not included. The birth years of the cohort members span the period 1883–1984 with a median of 1953. The cohort covers all branches of the Royal Navy, inclusive of the Coast Guard, the Coastal Artillery, and the Fleet, and is believed to comprise virtually all active military personnel in the Navy for the period [Strand et al., 2008]. The number of servicemen by duration of service in the Navy is shown in Figure 1 (all cohort members) and in Figure 2 (vessel crews). Data on work places and job titles were considered precise and specific. No measurements or written documentation on asbestos exposure at the personal level was available.

Case Identification and Analysis

Cancer cases in the cohort were identified by linkage to the Cancer Registry, which, due to compulsory reporting, is considered close to complete from 1953, recently assessed for the latest years [Cancer in Norway, 2007]. The linkage was based on 11-digit unique personal identification numbers

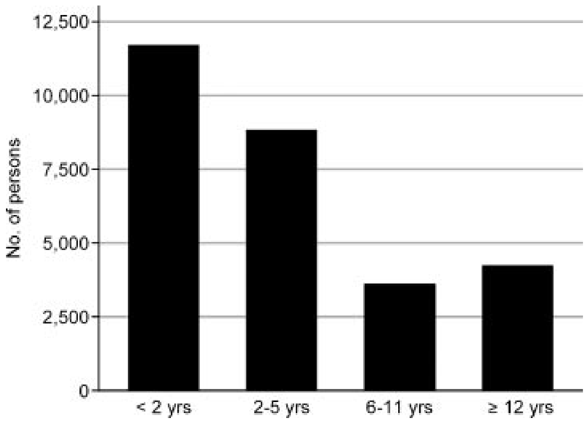

FIGURE 1. Number of personnel and total duration of service in the Navy during 1950–2004 (N = 28,345).

given to all citizens of Norway alive in 1960 or born later, and for cases diagnosed before 1960, on name and date of birth. Each cohort member was observed for cancer from the first date he entered service in the Navy, but no earlier than January 1, 1953, until date of death, date of emigration, or December 31, 2007, whichever came first.

The analysis was based on a comparison of the observed numbers of new cancer cases with those expected from the national rates according to 5-year age-specific and 5-year period-specific rates among all Norwegian men. The standardized incidence ratio (SIR) was calculated as the ratio between the observed and expected numbers, and 95% confidence intervals (CI) were computed on the assumption of a Poisson distribution of the cases. Poisson regression analysis was used to compare rates according to duty station aboard, with observation period and age at risk included in the models. Relative risks, expressed as rate ratios (RR) were calculated with reference to the incidence among ship crews who never served in the engine room. We determined the latency time for mesotheliomas as the time from start in asbestos-related work in the Navy until date of diagnosis.

Asbestos Exposure

For hygienic reasons asbestos was removed from the work environment aboard by refitting or disposal of vessels during the mid-1980s [Moen et al., 2005]. The last marine vessels to have asbestos removed were the five frigates, for which refitting started during 1986–1989, according to ship's logs. A subcohort of approximately 11,500 servicemen who had been serving aboard any time between 1950 and 1987 was regarded as exposed. Engine room crews were considered to experience higher exposure intensity than other crew members. Land-based personnel during the same period were considered to be unexposed, as work on land involving handling of asbestos—at workshops and shipyards mainly—was performed by civilians not included in this military cohort. After 1987, all types of service were considered as unexposed (Fig. 3). Service aboard was classified according to type of vessel (submarine or surface vessel) and work in engine rooms. Experience from engine rooms was identified by work-titles containing the words machinist, engine, greaser, stoker, or electrician, as these titles constitute the Navy's "Engine Compartment Group."

Follow-up according to duration of a particular service (such as engine room service) was conducted in the following way: All personnel starting with any particular service were followed according to the lowest category (shortest duration) until they qualified for a higher one. Those who never qualified for a higher category were followed according to the lower one throughout their entire follow-up time. A cut-point of only 2 years length of service was chosen because most navy personnel had a rather short total service. Forty-four percent of the personnel in our cohort quit the Navy before

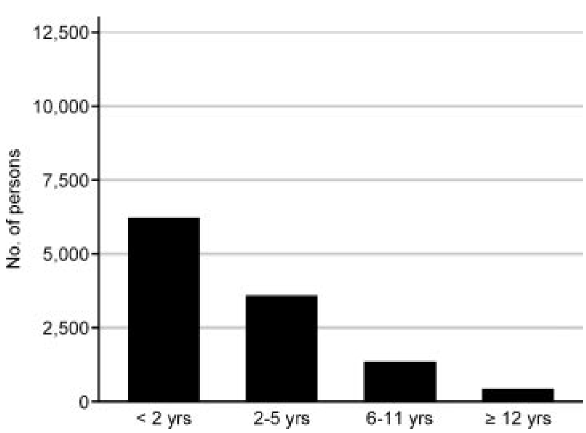

FIGURE 2. Number of personnel and total cumulative duration of service aboard during 1950–1987 (N = 11,491).

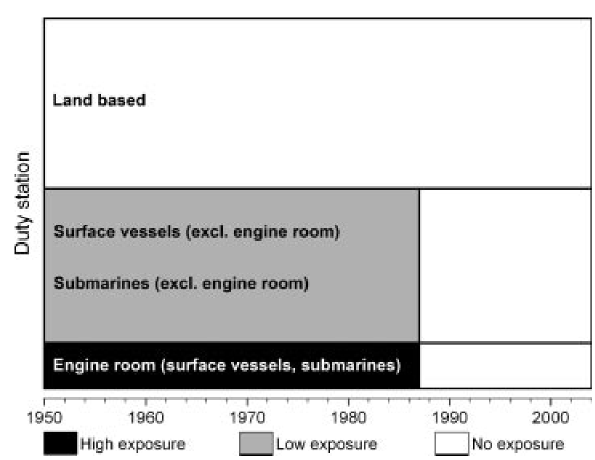

FIGURE 3. Exposure by duty station and time period. The height of each rectangle reflects the number of persons in each category.

2 years, and 54% of ship crews served aboard for less than 2 years.

Asbestos is the only environmental factor known to cause malignant mesothelioma. The Simian Virus 40 (SV40), which was a possible contaminant in polio vaccines used in Norway during 1956–1962 [Ulvestad et al., 2003], has been debated as a co-carcinogen, but recent studies have found no link [Leithner et al., 2006; Kjaerheim et al., 2007]. For the present study, an elevated incidence of mesotheliomas therefore served as an indicator of asbestos exposure. The incidence of other potentially asbestos-related cancers (lung cancer, laryngeal, pharyngeal, stomach, and colorectal cancers) was evaluated according to work experience and mesothelioma excess. The cancers were classified according to the International Classification of Diseases, 7th revision (ICD 7). Location 163 (pleura) and 158 (peritoneum) are cancers located in the mesothelium, but not exclusively mesotheliomas. We based our incidence data—observed cases and reference rates—on histologically or morphologically verified mesotheliomas.

The study was approved by the Norwegian Data Inspectorate, the Regional Ethics Committee, and the Norwegian Directorate of Health.

RESULTS

The SIRs for asbestos-related cancers and all cancers combined for all personnel and exposed and unexposed personnel are shown in Table I. In the total cohort, the risk of all cancers combined was slightly higher than expected (SIR = 1.04; 95% CI = 1.01–1.08). Among personnel regarded as unexposed, no increased risk was seen for all cancers combined nor for asbestos-related cancers. The SIR for lung cancer was 23% lower than the national rates (0.77; 95% CI = 0.64–0.92). Service aboard for less than 2 years was associated with an increased risk of all cancers combined

TABLE I. Cancer of All Sites Combined and Asbestos-Related Sites in All Personnel, in Personnel Regarded as Unexposed, and in Personnel With Less Than 2 Years, or 2 Years or Longer Service Aboard the Vessels Between 1950 and 1987 (N = 28,345; 889,190 person years at risk; Follow-Up: 1953–2007)

Site	ICD-7	Personnel group	Obs.	Exp.	SIR	95% CI
All cancers combined	140–204	All personnel	3,085	2,955.8	1.04	1.01–1.08
		Unexposed	1,309	1,361.9	0.96	0.91–1.01
		Vessel <2 years	976	893.3	1.09	1.03–1.16
		Vessel ≥2 years	800	700.5	1.14	1.07–1.22
Mesothelioma	158 + 163	All personnel	22	13.3	1.65	1.04–2.50
		Unexposed	5	5.8	0.86	0.28–2.00
		Vessel <2 years	7	4.1	1.69	0.68–3.49
		Vessel ≥2 years	10	3.3	3.00	1.44–5.51
Trachea, bronchus, and lung	162	All personnel	345	346.5	1.00	0.90–1.11
		Unexposed	118	154.2	0.77	0.64–0.92
		Vessel <2 years	120	106.3	1.13	0.94–1.35
		Vessel ≥2 years	107	86.1	1.24	1.03–1.50
Larynx	161	All personnel	28	33.1	0.85	0.56–1.22
		Unexposed	10	14.7	0.68	0.33–1.25
		Vessel <2 years	12	10.2	1.18	0.61–2.06
		Vessel ≥2 years	6	8.2	0.73	0.27–1.60
Pharynx	145–148	All personnel	28	26.8	1.04	0.69–1.51
		Unexposed	8	12.2	0.66	0.28–1.29
		Vessel <2 years	8	8.3	0.97	0.42–1.90
		Vessel ≥2 years	12	6.4	1.88	0.97–3.28
Stomach	151	All personnel	104	109.4	0.95	0.78–1.15
		Unexposed	43	51.6	0.83	0.60–1.12
		Vessel <2 years	33	32.3	1.02	0.70–1.44
		Vessel ≥2 years	28	25.6	1.09	0.73–1.58
Colon and rectum	153 + 154	All personnel	395	381.5	1.04	0.94–1.14
		Unexposed	175	172.0	1.02	0.88–1.18
		Vessel <2 years	113	116.3	0.97	0.81–1.17
		Vessel ≥2 years	107	93.2	1.15	0.95–1.39

ICD, International Classification of Diseases; Obs., observed number of cases; Exp., expected number of cases based on population rates; SIR, standardized incidence ratio; CI, confidence interval.

of 9% (SIR = 1.09; 95% CI = 1.03–1.16). For personnel who served longer aboard the risk increased to 14% (SIR = 1.14; 95% CI = 1.07–1.22), including a tripled risk of mesothelioma (SIR = 3.00; 95% CI = 1.44–5.51) and a 24% increased risk of lung cancer (SIR = 1.24; 95% CI = 1.03–1.50).

Table II presents the results for all ship crews, further divided into personnel with no service in engine rooms, and those with engine room experience for less than 2 years, and 2 years or more. Personnel who never served in the engine room showed the highest risk of all cancers combined (SIR = 1.14; 95% CI = 1.08–1.21), partly as a result of contributions from lung cancer (SIR = 1.18; 95% CI = 1.01–1.37) and colorectal cancer (SIR = 1.14; bordering on statistical significance with a 95% CI of 0.98–1.32). Engine room service was associated with a sixfold increase in mesotheliomas for both the shorter and longer service duration categories (SIR = 6.23; 95% CI = 2.51–12.8 and SIR = 6.49; 95% CI = 2.11–15.2, respectively).

The Poisson regression analysis (Table III) showed a sevenfold increased rate of mesotheliomas in personnel who served in the engine room, compared with personnel who served aboard but never in the engine room. The effect of service length was negligible. For lung cancer, no effect of duty station was found.

In Table IV, the results for submariners who ever or never served in the engine room are presented. Those with no engine room service showed a 20% increased risk of all cancers combined (SIR = 1.20; 95% CI = 1.04–1.38), including non-significant increases in lung, pharyngeal, stomach, and colorectal cancers. A suggested moderate increase of mesothelioma in submariners was based on two cases only.

Submariners constitute a little less than 18% of the total crew numbers and person years presented in the heading of Table II. The cancer incidence pattern among surface vessel crews was quite similar to that of all vessel crews and is not presented.

The median latency time for the 12 mesothelioma cases among engine room crews was 41 years, ranging from 28 to 48 years from first job in engine room until date of diagnosis. Duration of engine room service ranged from 3 months to 6.3 years, with a median of 1.3 years.

DISCUSSION

Our study showed no elevated risk of all cancers combined or asbestos-related cancers among personnel without service aboard the vessels during 1950–1987. On the other hand, service aboard was associated with an overall

TABLE II. Cancer Risk Among Personnel With Service Aboard Vessels, Among Crews Who Never Served in the Engine Room, Who Served in the Engine Room for Less Than 2 Years, or 2 Years or More Between 1950 and 1987 (N = 11,491; 426,860 Person-Years; Follow-Up: 1953–2007)

Site	ICD-7	Duty station (all vessels)	Obs.	Exp.	SIR	95% CI
All cancers combined	140–204	Never engine	1,371	1,198.6	1.14	1.08–1.21
		Engine <2 years	233	233.1	1.00	0.88–1.14
		Engine ≥2 years	172	161.3	1.07	0.92–1.24
Mesothelioma	158 + 163	Never engine	5	5.6	0.90	0.29–2.09
		Engine <2 years	7	1.1	6.23	2.51–12.8
		Engine ≥2 years	5	0.8	6.49	2.11–15.2
Trachea, bronchus, and lung	162	Never engine	170	144.6	1.18	1.01–1.37
		Engine <2 years	36	28.1	1.28	0.90–1.78
		Engine ≥2 years	21	19.7	1.07	0.66–1.63
Larynx	161	Never engine	13	13.8	0.94	0.50–1.61
		Engine <2 years	4	2.7	1.49	0.40–3.80
		Engine ≥2 years	1	1.9	0.53	0.01–2.96
Pharynx	145–148	Never engine	17	11.0	1.55	0.90–2.47
		Engine <2 years	2	2.2	0.92	0.11–3.33
		Engine ≥2 years	1	1.5	0.67	0.02–3.74
Stomach	151	Never engine	50	43.8	1.14	0.85–1.50
		Engine <2 years	7	8.1	0.86	0.35–1.77
		Engine ≥2 years	4	5.9	0.68	0.18–1.74
Colon and rectum	153 + 154	Never engine	179	157.5	1.14	0.98–1.32
		Engine <2 years	20	30.6	0.65	0.40–1.01
		Engine ≥2 years	21	21.4	0.98	0.61–1.50

ICD, International Classification of Diseases; Obs., observed number of cases; Exp., expected number of cases based on population rates; SIR, standardized incidence ratio; CI, confidence interval.

TABLE III. Relative Risk According to Engine Work, Expressed as Rate Ratios (RRs) of Mesothelioma and Lung Cancer Among Ship Crews, Using Poisson Regression Analysis Adjusted for Observation Period and Age

	Mesothelioma		Trachea, bronchus, and lung	
Duty station (all vessels)	RR	95% CI	RR	95% CI
Never engine	1.0 (ref.)	—	1.0 (ref.)	—
Engine <2 years	6.76	2.14–21.3	1.09	0.76–1.56
Engine ≥ 2 years	7.26	2.10–25.1	0.92	0.58–1.44

RR, rate ratio; CI, confidence interval.

increased risk of cancer. Excess lung cancer and mesothelioma incidence were seen only among vessel crews, for mesothelioma, limited largely to those with experience from the engine rooms.

The cohort was established from a highly reliable source, namely the personnel database at Headquarters Defense Command Norway, and is regarded as virtually complete. The service histories are detailed, with dates and job descriptions. The use of the unique personal identification numbers ensured correct identification and linkage to the national cancer database at the Cancer Registry of Norway, which is considered complete from 1953. The method of identification and linkage should assure correct and unbiased results.

Due to the WWII, when Norway was occupied by Nazi Germany, historical service files before 1950 were incomplete or missing. This lack of data could potentially lead to misclassification of personnel according to duration of service and duty stations. The lack of individual data on smoking and asbestos exposure, both important risk factors for lung cancer, clearly limited the interpretation of the results for this cancer type.

Malignant Mesothelioma

We observed 22 cases of malignant mesothelioma, which were all located in the pleura and diagnosed between 1983 and 2007. A ratio of pleural-to-peritoneal mesotheliomas of 9:2 has been reported among Norwegian insulation workers [Ulvestad et al., 2004], while the corresponding ratio among 2,165 male cases in Italy was 25:1 [calculated from data in Marinaccio et al., 2007]. Browne and Smither [1983] observed an increase in the proportion of peritoneal cases with a longer duration of exposure. The absence of peritoneal mesothelioma in our study corresponded to short exposure time, but we have no data on lifetime asbestos exposure and lack the statistical strength to pursue this question further.

There was no excess of mesothelioma in personnel defined as unexposed, that is, personnel who did not serve aboard during 1950–1987, or in personnel who served aboard but never in the engine room. Of the five cases among "unexposed" personnel, four had been serving at Coastal forts, the last person served as an instructor at a maritime school. Regarding the five cases in non-engine-room crews aboard, four had served at the bridge whereof three also have served at the (land-based) maritime schools, and one was a boatswain with radar and plotting training.

An increasing trend with length of service aboard was suggested, but engine room work proved to be a much stronger

TABLE IV. Cancer Risk Among Submariners With and Without Service in the Engine Room Between 1950 and 1987 (N = 2,038; 74,678 person-years; Follow-Up: 1953–2007)

Site	ICD-7	Duty station (submarines)	Obs.	Exp.	SIR	95% CI
All cancers combined	140–204	Never engine	200	166.7	1.20	1.04–1.38
		Engine room	93	88.6	1.05	0.85–1.29
Mesothelioma	158 + 163	Never engine	1	0.8	1.27	0.03–7.05
		Engine room	1	0.4	2.35	0.06–13.1
Trachea, bronchus, and lung	162	Never engine	23	19.9	1.16	0.73–1.74
		Engine room	7	10.6	0.66	0.27–1.36
Larynx	161	Never engine	0	1.9	0.00	0.00–1.93
		Engine room	2	1.0	1.97	0.24–7.10
Pharynx	145–148	Never engine	4	1.6	2.47	0.67–6.32
		Engine room	0	0.8	0.00	0.00–4.37
Stomach	151	Never engine	9	5.4	1.66	0.76–3.14
		Engine room	0	2.9	0.00	0.00–1.26
Colon and rectum	153 + 154	Never engine	28	21.6	1.30	0.86–1.88
		Engine room	13	11.6	1.12	0.60–1.92

ICD, International Classification of Diseases; Obs., observed number of cases; Exp., expected number of cases based on population rates; SIR, standardized incidence ratio; CI, confidence interval.

predictor of mesothelioma risk. A sixfold risk of mesotheliomas among crews serving less than 2 years in the engine room seems rather high for personnel whose main activity was not handling of asbestos. Such a relative risk might be due to fiber type, intensity of exposure, and/or exposure outside the Navy. According to a review by Ribak and Ribak [2008] there is a gradient in the risk of mesotheliomas between different types of asbestos, with crocidolite (blue asbestos) and amosite (brown asbestos) conveying a greater risk than chrysotile (white asbestos). Although the latter type was most commonly applied aboard, suspended brown asbestos was detected alow both inside and outside the engine room on a frigate [Moen et al., 2005]. Brown asbestos has also been found aboard Norwegian civilian vessels inspected during the 1970s by DNV Maritime, an independent Norwegian foundation on ship inspection. Short duration of exposure has been reported to be sufficient to cause mesotheliomas. From 66 pleural mesothelioma cases among British asbestos factory workers, 30 cases (45%) followed exposure lasting less than 2 years [Browne and Smither, 1983].

The risk did not seem to increase with increasing length of service in the engine room. Possibly, asbestos exposure outside the Navy may have influenced the rates and obscured the effect of service length in the Navy. Skilled engine room workers typically obtain their education in the Navy. Five of the seven cases with less than 2 years of service in engine rooms were enlisted personnel. A typical contract period for enlisted personnel was 3 years, which includes 1–2 years of education, followed by obligatory vessel service. Furthermore, enlisted personnel were not obliged for compulsory service and mobilization. An ultimate intention of enlistment might have been to sign on to civilian vessels, rather than having a military career.

Incomplete service history files from before 1950 could create misclassification of exposure. Five of the mesothelioma cases in our study had an unrecorded Navy career before 1950. Two of them had served aboard the vessels after 1950, but not in the engine room, and three belonged to the unexposed group. A normal Navy career for vessel crews is a shift towards land-based jobs later in life, and the contrast between rates in exposed and unexposed might therefore be underestimated.

For the 12 mesothelioma cases in engine room crews, the latency ranged from 28 to 48 years, with a median of 41 years. For other mesothelioma cases, start of exposure was unknown, and latency could not be estimated. An extended follow-up will probably increase the upper range limit. Ideally, range and median should not be calculated before all potential mesotheliomas are manifested, implicating a lifetime follow-up of the cohort.

Lung Cancer

The differences in lung cancer incidence were small, and the lack of data on smoking history calls for a cautious interpretation only. The overall number of cases was close to that expected, but interestingly, the risk among non-exposed personnel (land-based only or vessel service after 1987 only) was significantly lower than expected, and significantly elevated among vessel crews that served for 2 years or more. Some information suggests that the variation in risk may be due to differences in smoking habits. The Coastal Artillery, the largest land-based branch of the Navy, typically offer work in coastal forts located underground, where personnel used to live day-round while on duty. Smoking was prohibited in these premises, at least where ammunition and torpedoes were stored, and the smoke-free environment may have disencouraged smokers from applying for such service. A separate analysis performed among 6,119 personnel with registered service in coastal forts during 1950–2004 showed a low incidence of lung cancer, with a SIR of 0.62 (95% CI = 0.44–0.85; follow-up from 1953 through 2005, unpublished data presented to the Navy Medical Corps in 2007). The similar reasoning can be used for submariners, as smoking while submerged was not allowed. The elevated risk among vessel crews was only observed among those with service from surface vessels.

Among personnel with any vessel service, the lung cancer incidence ratio did not differ between non-engine crews (SIR = 1.18; 95% CI = 1.01–1.37) and those with engine room experience (irrespective of length) (SIR = 1.19; 95% CI = 0.91–1.55; Table II), while excess mesotheliomas were seen only in the latter group. Thus, when mesothelioma incidence was taken as an indicator of the presence or absence of asbestos exposure, no consistent pattern was seen for a corresponding lung cancer incidence. Theoretically, adjustment for smoking could reveal such effects, but it is not likely to be large.

Other Asbestos-Related Cancers

The observed numbers of laryngeal, pharyngeal, stomach, and colorectal cancers did not differ significantly from the expected numbers in any subgroup. Slight excess of pharyngeal, stomach, and colorectal cancers were observed only among non-engine crews aboard the vessels, suggesting no link to asbestos exposure.

CONCLUSION

Only mesotheliomas located in the pleura were found in this study. Excess mesothelioma risk was observed among engine room crews aboard vessels. The latency time for cases among engine room crews ranged from 28 to 48 years, with a median of 41 years. When mesothelioma incidence was taken as an indicator of the presence or absence of asbestos exposure, the data did not suggest an effect on other airway cancers, stomach, or colorectal cancers.

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