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Cancer Due to Asbestos Exposure*

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To determine the relationship between malignancies and asbestos exposure, the number of asbestos bodies in wet lung tissue was counted by light microscopy according to the modified method of Smith and Naylor, and occupational histories were examined. The results revealed that 17 (89 percent) of 19 malignant mesotheliomas, 39 (38 percent) of 104 lung cancers, 23 (37 percent) of 62 gastric cancers, and 13 (28 percent) of 45 colon cancers were shown to be cases with asbestos exposure. These values were significantly higher than those of noncancerous cases (200 cases). It is of interest that five out of ten cases of leukemia were related to asbestos exposure. Nearly all multiple cancers including lung and gastric cancer in this study were also cases with asbestos exposure. Additional research should be conducted on the carcinogenicity of asbestos for multiple cancers.

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Asbestos has been implicated in malignant mesotheliomas; and recently, many other malignancies, such as lung cancer and cancers of the gastrointestinal tract, have also been reported to be related to asbestos exposure. This study was conducted to determine the relationship of malignancies to asbestos exposure by counting the asbestos bodies in wet lung tissue and the types of asbestos fibers.

Materials and Methods

From 1984 to 1989, autopsies were performed at Kure Kyosai Hospital on 533 patients who had resided in the city or suburbs of Kure, Japan. Lung cancer accounted for 104 cases, malignant mesotheliomas for 19, gastric cancers for 62, colon cancers for 45, leukemia for ten, other malignancies for 93, and noncancerous for 200. The numbers of asbestos bodies in wet lung tissue from these 533 cases were counted by the modified method of Smith and Naylor, as shown previously.[2] Briefly, 5 g of lung tissue (without tumor involvement) were lysed in sodium hypochloride for 48 hours. Asbestos bodies were separated by an equal volume (20 ml) of chloroform (Wako; Osaka) and 50 percent ethanol (Wako; Osaka) and were centrifuged at 180 g for 5 minutes. The bottom fraction was filtered on a 5μ Millipore filter. Finally, the numbers of asbestos bodies were counted on the filters by light microscopy (×200). Asbestos fibers were also obtained by the same method and filtered on 0.5μ nuclear filters (Nucleopore). Samples were dehydrated by alcohol and sputter coated by carbon. Asbestos fibers were then observed by scanning electron microscopy (JEOL T-330) and analyzed by a metal analyzer (Seiko; Tokyo). The types of asbestos fibers were determined based on the UICC standard reference.[3]

For identification, types and percentages of metals in the asbestos fibers were examined, and asbestos fiber types were determined. At least 50 asbestos fibers in each case were examined. Asbestos bodies were also counted in the following noncancerous cases: 30 cases of cerebrovascular accidents; 27 myocardial infarctions; 16 cases of tuberculosis of the lung; 42 cases of cirrhosis of the liver; 36 cases of pneumonia; and 49 others. In this study, we used nonparametric analysis conducted using Kruskal-Wallis one-way analysis of variance and the multiple comparison method of Dun.[4]

Results

From 1984 to 1989 at this hospital, 19 cases of malignant mesothelioma were treated. The details of 18 of these cases have been reported previously.[5] Table 1 presents the details for all 19 cases. The most common site of malignancy was of pleural origin in 16 cases; there were two cases of peritoneal origin and one of pericardial origin. Grouped according to sex, there were 17 men and 2 women. Thirteen of the men and one woman had worked in a Japanese naval shipyard or some other shipyard, and their occupational histories indicated asbestos exposure. Only four cases, three men and one woman, revealed no clear relationship to asbestos exposure. Asbestos bodies detected in 5 g of wet lung tissue ranged from 522 to 266,500 in number, thus confirming high asbestos exposure[6] (Fig 1). Crocidolite was the main type of asbestos for 8 of 11 malignant mesotheliomas. Amosite was mainly detected in four cases. Chrysotile was also found but was not the main component for two cases. Tumor latency was at least 20 years following the first exposure. The average latency period was 40 years. The average duration of asbestos exposure was 24 years. By statistical analysis, no relationship could be found between exposure time and asbestos bodies in lung tissue.

Cases confirmed to have lung cancer based on postmortem results were investigated for a relationship to asbestos exposure. As shown in Figure 1, autopsies were performed in 104 cases, 92 male and 12 female patients. Of these, 39 cases (37 [40 percent] of the male patients and 2 [17 percent] of the female patients) were considered possible cases of asbestos-related lung cancer based on the presence of 500 or more asbestos bodies in 5 g of postmortem lung tissue. The incidence of these cases was 38 percent (39/104) of all of the cases. Ages ranged from 53 to 82 years; and for elderly patients, 80 percent were 65 years or more. Based on histologic type, there were 16 cases (41 percent) of the squamous cell type, 22 cases (56 percent) of the adenocarcinoma type, and 1 case (3 percent) of the small-cell type. The number of asbestos bodies in lung cancer was significantly higher ($p<0.01$)

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Table 1—*Cases of Malignant Mesothelioma*

Case, Sex, Age, yr	Origin	Histology	Occupational History	Asbestos Bodies	Types of Asbestos Fiber (Main Component)	Duration, yr	Latency, yr
1,M,61	Peritoneal	Biphasic	Shipfitter at shipyard	15,965	. . .	12	36
2,M,75	Left pleura	Sarcoma	Welder at shipyard	2,669	. . .	25	48
3,M,61	Left pleura	Biphasic	Farmer	. . .	. . .	?	?
4,M,49	Left pleura	Biphasic	Asbestos factory (asbestos mixture)	4,404	. . .	5	20
5,M,64	Peritoneal	Epithelioma	Welder at shipyard	. . .	. . .	10	20
6,F, 79	Pericardium	Epithelioma	Laborer at Japanese naval shipyard	975	Crocidolite; amosite	10	40
7,M,67	Left pleura	Biphasic	Shipfitter at Japanese naval shipyard	12,225	Amosite	34	45
8,M,77	Left pleura	Epithelioma	Carpenter at Japanese naval shipyard	1,333	Crocidolite	3	43
9,M,77	Left pleura	Biphasic	Laborer at Japanese naval shipyard	38,400	Amosite	31	47
10,M,71	Right pleura	Sarcoma	Watchman at Japanese naval shipyard	522	Crocidolite	27	43
11,M,62	Right pleura	Epithelioma	Steel company, crane operator	525	Crocidolite; chrysotile	5	25
12,M,76	Left pleura	Sarcoma	Welder at Japanese naval shipyard	149,160	Amosite	5	48
13,M,70	Left pleura	Biphasic	Welder at Japanese naval shipyard	93,805	Crocidolite; chrysotile	24	49
14,M,57	Right pleura	Biphasic	Driver at railroad	. . .	. . .	?	?
15,F, 46	Right pleura	Sarcoma	Housekeeper	. . .	. . .	?	?
16,M,67	Left pleura	Sarcoma	Welder at shipyard	30,126	Crocidolite	20	30
17,M,69	Right pleura	Epithelioma	Laborer at shipyard	2,202	Crocidolite	6	40
18,M,56	Left pleura	Biphasic	Carpenter at shipyard	266,560	Crocidolite	25	28
19,M,72	Left pleura	Epithelioma	Welder at Japanese naval shipyard	. . .	. . .	20	30

than that in noncancerous cases (Fig 1). Among the cases, those with large numbers of asbestos bodies had histories of asbestos exposure during employment at Japanese naval or other shipyards. This feature was also noted in cases of malignant mesothelioma; however, unlike cases of malignant mesothelioma, there were many cases without any clear occupational history of asbestos exposure. For lung cancer, almost all patients were heavy smokers (Brinkman index: more than 600), while one half of the patients with malignant mesothelioma were nonsmokers. Almost all asbestos fibers detected in cases of lung cancer were chrysotile, as described previously.[7]

Sixty-two cases of gastric cancer confirmed by postmortem findings were examined for the presence of 500 or more asbestos bodies per 5 g of lung tissue (Fig 1). These patients consisted of 53 male and 19 female patients, but all 23 cases (37 percent) having 500 or more asbestos bodies per 5 g of lung tissue were male patients. Age ranged from 52 to 86 years, and there were many elderly patients. Among the 23 cases positive for asbestos bodies, 20 patients (87 percent) were 65 years old or more. The number of asbestos bodies in the cases of gastric cancer was significantly higher ($p<0.01$) than that of noncancerous cases. Asbestos bodies and fibers could not be detected in the gastric cancer tissues. Most patients with more than 1,000 asbestos bodies per 5 g of lung tissue had occupational histories of possible exposure to asbestos while working at Japanese naval or other shipyards, as also noted for cases with malignant mesothelioma. Twenty-eight percent (13) of 45 colon cancers were also cases of asbestos exposure (data not shown), this number being significantly higher ($p<0.05$) than that of noncancerous cases.

In the period from 1984 through 1989, ten cases of leukemia were confirmed from postmortem findings, and the details are shown in Table 2. Cases 5 and 6 have been previously reported,[8] and chest x-ray films showed clear pleural plaques. Both cases had occupational histories of asbestos exposure due to shipyard work. A significant number of asbestos bodies was detected in lung tissues from cases 3, 4, 5, 6 and 8. Statistically, 50 percent of all of the ten cases had histories of asbestos exposure. Given that the remaining five patients were students or housekeepers with no history of asbestos exposure, the 50 percent incidence should be considered quite high.

Of 333 cases of malignant tumors confirmed by postmortem findings, 40 had multiple cancers (two or more). Ten (25 percent) of these 40 had multiple cancers consisting of lung and gastric cancers; Table 3 shows the details. All of the patients were elderly, with an age range of 67 to 76 years, and all were men.

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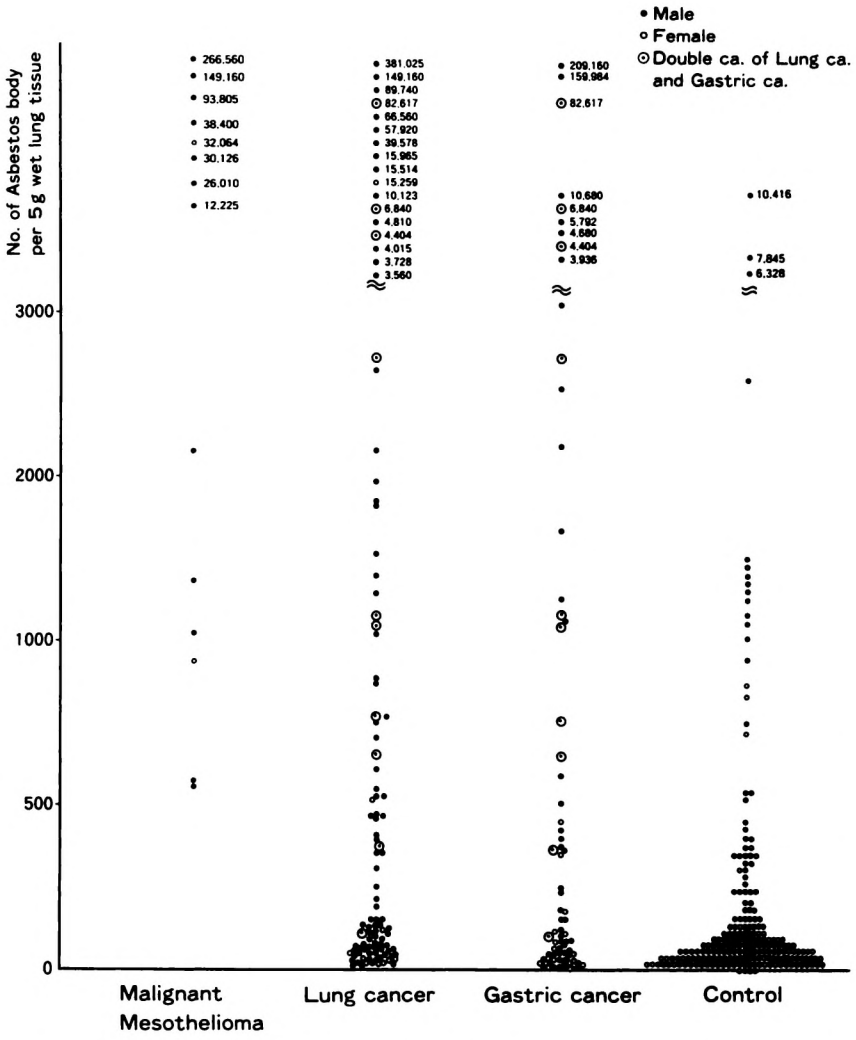


FIGURE 1. Numbers of asbestos bodies from autopsied lungs for cases of mesothelioma, lung cancer, gastric cancer, or noncancerous cases. Fourteen cases of malignant mesothelioma, 39 cases of lung cancer, and 23 cases of gastric cancer had more than 500 asbestos bodies in 5 g of lung tissue. Numbers of asbestos bodies for cases of malignant mesothelioma, lung cancer, and gastric cancer are significantly higher ($p<0.01$) than those of noncancerous cases. It is interesting that nine out of ten cases of double cancer consisting of lung and gastric cancers had more than 500 asbestos bodies.

Histologic typing of lung cancers showed five cases of small-cell carcinoma (SCC) and five cases of adenocarcinoma. The primary site of development of the malignancy was the upper lobe in seven cases. In all but one case, gastric cancers were early stage. Cure was achieved in five cases by surgery, with no relapse at the time of autopsy. The other four cases had a complication of type 2 c early-stage gastric cancer, but the cause of death was lung cancer. The history of smoking in these ten cases was investigated, and a score exceeding 700 on the Brinkman index was found in all cases, thus showing all of them to fall within the heavy-smoker category. From each of these ten cases, 5 g of lung tissue free of cancer invasion was solubilized in sodium hypochlorite solution, and large numbers of asbestos bodies, ranging from 103 to 82,617, were detected; however, the occupational history of three cases was not clear.

Of the remaining 30 cases of multiple cancers, three had a combination of gastric and colon cancers and showed no particular features. Twenty-four of the 40 cases had multiple cancers and lung or gastric cancer, a very large proportion. The mean count of asbestos bodies in these 24 cases was $11,373 \pm 6,342$, which was significantly higher ($p<0.05$) than the number of bodies in 16 cases with neither lung nor gastric cancer (Fig 2). The mean count of asbestos bodies per 5 g of lung tissue from cases of multiple cancers was $7,453 \pm 4,209$, and a count of $1,059 \pm 327$ was found for 200 cases confirmed by autopsy to have died due to nonmalignant disease.

DISCUSSION

The city of Kure in the prefecture of Hiroshima has been a major shipbuilding center for warships since the 1920s, and asbestos in ship construction may have been a major causative factor of malignant mesotheliomas in that region, based on the present study.

The relation between malignant mesothelioma and asbestos exposure was first reported by Wagner et al,[9] who found a high incidence of mesothelioma in crocidolite miners in South Africa. Since then, there have been many reports[10-12] throughout the world. Of these, 88 percent are of pleural malignant mesothelioma, 9.6 percent peritoneal, 0.7 percent pericardial, and 0.2 percent on the testicular sacs.[13] Approximately

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Table 2—*Cases of Acute Leukemia Related to Asbestos Exposure*

Case, Sex, Age, yr	Diagnosis*	Occupational Histories	No. of Asbestos Bodies per 5 g of Lung Tissue
1,F, 25	ATL	Housekeeper; no history of asbestos exposure	23
2,F, 39	ATL	Housekeeper; no history of asbestos exposure	10
3,F, 34	ATL	Housekeeper; living near shipyard for 20 yr	1,135
4,M,58	ATL	Shutter maker for 40 yr	2,528
5,M,59	AML	Arc welder at shipyard for 40 yr	37,766
6,M,77	AML	Shipbuilding at Japanese naval shipyard (40 yr)	540
7,M,25	AML	Student; no history of asbestos exposure	40
8,M,50	AMMOL	Carpenter for 30 yr	888
9,M,23	ALL	Student; no history of asbestos exposure	12
10,F, 18	APL	Student; no history asbestos exposure	5

*ALL, acute lymphocytic leukemia; AML, acute myelocytic leukemia; AMMOL, acute myelomonocytic leukemia; APL, acute promyelocytic leukemia; and ATL, acute T-cell leukemia.

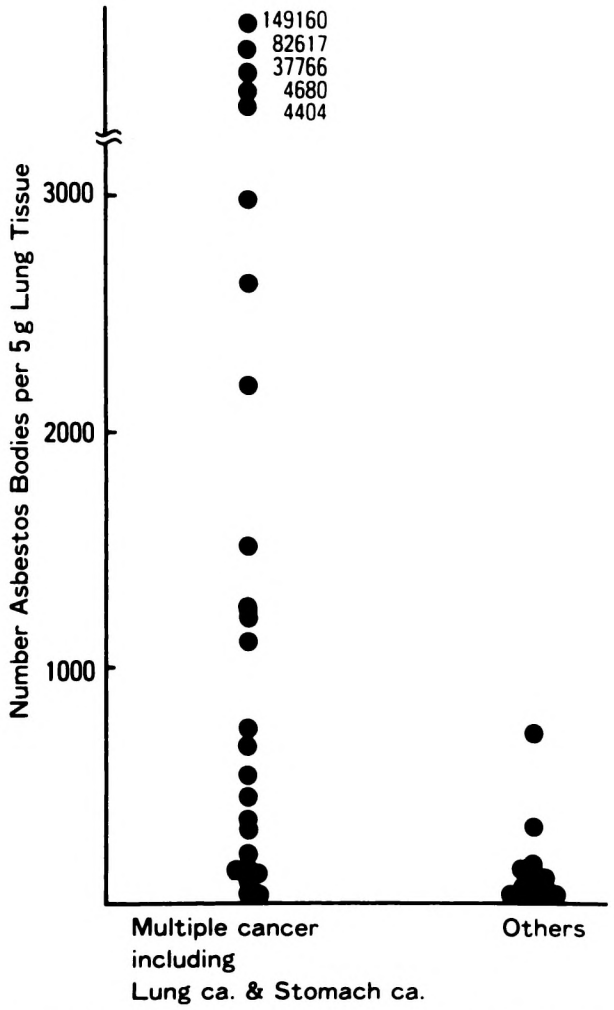


FIGURE 2. Numbers of asbestos bodies from autopsied lungs. Numbers of asbestos bodies from 24 double cancers including lung or gastric cancer are significantly higher ($p<0.01$) than those of 16 cases with multiple cancer not including lung or gastric cancer.

80 percent of diffuse malignant mesotheliomas have been found in men exposed to asbestos, and 20 percent have no history of exposure to asbestos. The carcinogenicity of asbestos for malignant mesotheliom has been confirmed by various studies.[14-16] About 70 percent of the cases of this disease in the United States and other Western countries is related to asbestos exposure at shipyards and large asbestos manufacturing and insulation factories. In Japan, less than 50 percent of the cases with malignant mesothelioma have been reported to be associated with asbestos exposure; however, in the past three years, about 60 percent of the cases of malignant mesothelioma described in Japanese journals have had histories of asbestos exposure. In the Kure area, asbestos has been in use since the 1920s; however, in many areas

Table 3—*Cases of Double Cancers (Lung and Stomach)*

Case, Sex, Age, yr	Lung Cancer		Gastric Cancer	Occupational History	Brinkman Index	Asbestos Bodies per 5 g of Lung
	Histology*	Origin				
1,M,73	SCC	Right S^6	After operation; no relapse	Railroad	885	4,404
2,M,73	SCC	Right S^3	Borrman 3	Farmer	800	658
3,M,76	Adenocarcinoma	Left S^{1+2}	After operation; no relapse	Farmer	1,000	103
4,M,67	SCC	Right S^1	After operation; no relapse	Driver	700	763
5,M,70	SCC	Right S^6	Type 2c	Shipyard	1,500	82,617
6,M,73	Adenocarcinoma	Right S^1	Type 2c	Shipyard	800	1,100
7,M,74	SCC	Left S^{1+2}	After operation; no relapse	Shipyard	900	368
8,M,69	Adenocarcinoma	Right S^1	Type 2c	Metal industry	1,200	1,152
9,M,71	Adenocarcinoma	Right S^6	After operation; no relapse	Shipyard	2,000	2,669
10,M,76	Adenocarcinoma	Right S^1	Type 2c	Japanese naval shipyard	1,650	6,840

*SCC, squamous-cell carcinoma.

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of Japan, asbestos has been massively used since the 1960s. Malignant mesotheliomas will increase in the next 20 years. Crocidolite has been found to be highly carcinogenic,[17] while chrysotile has not been conclusively shown to lead to malignant mesothelioma.[18] Other reports maintain that chrysotile may lead to malignant mesothelioma.[19,20] The present data show that almost all mesotheliomas were induced by crocidolite or amosite, and the two cases of pleural malignant mesothelioma were induced by chrysotile.

Lynch and Smith[21] first reported cases with asbestosis-complicated lung cancer in 1935. Since then, epidemiologic studies[22,23] have documented an association between bronchogenic carcinoma and occupational exposure to asbestos. Blot et al[24] emphasize the high incidence of lung cancer in people working at shipyards. Our data also support this report. The type of lung cancer induced by exposure to asbestos has been mainly peripheral adenocarcinoma in the inferior lobes,[25] but Auerbach et al[26] noted about 66 percent of their cases to be squamous cell carcinoma in the upper lobes. Churg[27] found the type of lung cancer induced by asbestos exposure and tumor position to vary. In our cases, adenocarcinoma constituted 56 percent (22/39) of the asbestos-induced lung cancers, and tumor position varied. Vena et al[28] reported the incidence of squamous cell carcinoma and adenocarcinoma to increase with the term of asbestos exposure and small-cell carcinomas to also increase with the time of exposure and the degree of smoking. The carcinogenicity of asbestos in lung cancer is still not completely understood, but the association with smoking cigarettes is definite.[29-31] There is only a slight increase in the prevalence of lung cancer among nonsmokers, whereas heavy smokers exposed to asbestos have an 80-fold to 90-fold greater predisposition to lung cancer.[32] In this study, almost all of the 39 cases were heavy smokers. There are important medicolegal ramifications concerning the possible causal role of asbestos in lung cancer. The adsorption of the carcinogen, benzopyrene, has been shown to be the initial event in asbestos causing lung cancer.[33] The present data show about 40 percent of the cases of lung cancer are related to asbestos exposure, the main component of asbestos-induced lung cancer being chrysotile or tremolite. Almost all of the patients were heavy smokers. It is quite interesting that crocidolite or amosite was detected in most cases of malignant mesothelioma, whereas chrysotile or tremolite was detected in lung cancer. There are few reports[34] which treat lung cancer and chrysotile exposure, but chrysotile was the strongest asbestos absorbent of benzopyrene. Our data are consistent with these findings; however, other reports[35,36] indicate possibly a higher carcinogenic potential for crocidolite than chrysotile. The carcinogenicity of asbestos has been clarified by studies on occupational groups exposed to either type of asbestos or both together.

For cancer of the GI tract, Selikoff et al[37] indicated a significant twofold to threefold increase in such cancer in the GI tracts of insulation factory workers and shipyard employees. Other studies show gastric and colon cancers to have a significantly high incidence due to asbestos exposure;[38] however, no apparent dose-response relationship between the accumulated asbestos dose and the risk of GI cancer has been found. The association of asbestos with GI cancer has only recently been recognized, possibly due to its less common occurrence.[39] In this study, 37 percent (23/62) of the gastric cancers were in cases of asbestos exposure, as was also the case for lung cancer. About 50 percent of the asbestos fibers ingested enter the peritoneum to possibly induce peritoneal mesthelioma and cancers in the GI tracts.[40-43] There is no clinical evidence that asbestos induces such cancers. The relationship between asbestos exposure and GI tract cancers should thus be studied.

Chronic lymphocytic leukemia and malignant lymphoma are reported to be related to asbestos exposure.[44,45] Kagan and Jacobson[46] have described the relation of lymphoid and plasma cell malignancies to asbestos exposure but give no definitions. Asbestos fibers are transported to the various organs by the lymphatic system.[47] In cases of asbestosis of the lung induced by intense inhalation of asbestos fibers, proliferation of B-lymphocytes has been confirmed and dysfunction of B-lymphocytes attributed to B-cell malignancies. We encountered one case of multiple myeloma and one case of malignant lymphoma in asbestos-exposed patients. This incidence accounted for 13 percent of these two malignancies. Asbestos was found in the bone marrow of cases with acute myelocytic leukemia (cases 5 and 6). The route of asbestos transport would thus appear to be the bloodstream. Fifty percent of the cases of acute leukemia were cases highly exposed to asbestos, indicating possible carcinogenicity of leukemia by exposure to asbestos, but the relationship between leukemia and the carcinogenicity of asbestos is still unclear.

Finally, for multiple cancers, Dohner et al[48] found the multiple primary tumors to be induced by asbestos exposure. Their cases consist primarily of lung cancers; however, the relationship between other multiple primary tumors and asbestos exposure has yet to be reported. Nearly all of the present cases with multiple cancers including gastric and lung cancers had asbestos exposure, and the clinical courses for a total of ten cases were essentially the same. The numbers of asbestos bodies for multiple cancers including lung cancer or gastric cancer are significantly much more than for other types of multiple cancers. Multiple cancers including lung and gastric cancers should thus

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occur easily in people exposed to asbestos. The relationship between multiple cancers and asbestos exposure should thus be studied in greater detail.

References

1 Smith MJ, Naylor B. A method for extracting ferruginous bodies from sputum and pulmonary tissue. Am J Clin Pathol 1972; 58: 250-54
2 Kishimoto T, Okada K. The relationship between lung cancer and asbestos exposure. Chest 1988; 94:486-90
3 Timbrell V, Gilson JC, Webster I. UICC standard reference samples of asbestos. Int J Cancer 1986; 3:406-08
4 Soda R, Tavassoli M, Barnes TY. Mapping of the bone marrow sinus endothelium with lectins and glycosylated ferritins: identification of differentiated microdemains and their functional significance. J Ultrastruct Res 1983; 84:299-310
5 Kishimoto T, Stato T, Ono T, Okada K, Masuda Y, Ito H. Malignant mesotheliomas in Kure City, Japan: relationship of asbestos exposure. Cancer Invest 1989; 7:407-10
6 Churg A. Asbestos fiber content of the lungs in patients with and without asbestos airway disease. Am Rev Respir Dis 1983; 127:470-73
7 Kishimoto T, Okada K. Relationship between lung cancer and asbestos exposure. Chest 1988; 94:486-90
8 Kishimoto T, Ono T, Okada K. Acute myelocytic leukemia after exposure to asbestos. Cancer 1988; 62:787-90
9 Wagner JC, Sleggs CA, Marchand P. Diffuse pleural mesothelioma and asbestos exposure in the North Western Cape Province. Br J Ind Med 1960; 17:260-71
10 Stumphius J. Mesothelioma incidence in a Dutch shipyard. Ann NY Acad Sci 1979; 77:317-30
11 Blot WJ, Fraumeni JF, Morris LE. Cancer mortality in US countries with shipyard industries during World War II. Environ Res 1979; 18:281-90
12 Hulks G, Thomas JJ, Waclawski E. Malignant pleural mesothelioma in Western Glasgow 1980-6. Thorax 1989; 44:496-500
13 Hillerdal G. Malignant mesothelioma 1982: review of 4,710 published cases. Br J Dis Chest 1983; 77:321-43
14 Gardner MJ, Acheson ED, Winter PD. Mortality from mesothelioma of the pleural during 1968-78 in England and Wales. Br J Cancer 1982; 46:81-8
15 Sheers G. Mesothelioma risks in a naval dockyard. Arch Environ Health 1980; 35:276-82
16 Tagnon I, Blot WT, Stroube RB, Oay NE, Morris LE, Peace BB, et al. Mesothelioma associated with the shipbuilding industry in coastal Virginia. Cancer Res 1980; 40:3875-95
17 Wagner JC. Experimental studies and the pathology of asbestos-induced lung diseases. Arch Immunol Ther Exp 1982; 30:221-28
18 Davis JMG, Beckett ST, Bolton RE. The effects of intermittent high asbestos exposure (peak dose levels) on the lungs of rats. Br J Exp Pathol 1980; 61:272-80
19 Mancuso TF. Relative risk of mesothelioma among railroad machinists exposed chrysotile. Am J Ind Med 1988; 13:639-57
20 Churg A. Chrysotile, tremolite, and malignant mesothelioma in man. Chest 1988; 93:621-29
21 Lynch KM, Smith WA. Pulmonary asbestosis: 3. carcinoma of lung in asbestos-silicosis. Am J Cancer 1935; 24:56-64
22 Doll R. Mortality from lung cancer in asbestos workers. Br J Ind Med 1955; 12:81-6
23 Mancuso TF, Coulter EJ. Methodology in industrial health studies: the cohot approach with special reference to an asbestos company. Arch Environ Health 1963; 6:210-26
24 Blot WJ, Harrington JM, Toledo A. Lung cancer after employment in shipyard during Wald War II. N Engl J Med 1978; 299: 620-24
25 Kannerstein M, Churg J. Pathology of carcinoma of the lung associated with asbestos exposure. Cancer 1972; 30:14-21
26 Auerbach D, Gratiukel L, Parkers VR. histological type of lung cancer and asbestos exposure. Cancer 1984; 54:3017-21
27 Churg A. Lung cancer cell type and asbestos exposure. JAMA 1985; 253:2984-85
28 Vena LE, Byers TE, Cookfair D. Occupational and lung cancer risk: an analysis by histologic subtype. Cancer 1985; 56:910-19
29 Steenland K, Thun M. Interaction between tobacco smoking and occupational exposures in the causation of lung cancer. J Occup Med 1986; 28:110-18
30 Berry G, Newhouse MC, Turok M. Combined effects of asbestos exposure and smoking on mortality from lung cancer in factory workers. Lancet 1972; 2:476-78
31 Craighead JE, Mossman BT. The pathogenesis of asbestos-associated diseases. N Engl J Med 1982; 306:1446-55
32 Woodworth CD, Mossman BT, Craighead JE. Squamous metaplasia of the respiratory tract: possible pathogenic role in asbestos-associated bronchogenic carcinoma. Lab Invest 1983; 48:578-84
33 Kimizuka G, Ohwada H, Hayashi Y. Cocarcinogenic effect of asbestos and benzopyrene in the lung of hamster. Acta Pathol Jpn 1987; 37:465-74
34 McDonald AD, Fry JS, Woolley AJ, McDonald J. Dust exposure and mortality in an American chrysotile textile plant. Br J Ind Med 1983; 40:361-67
35 Mossman B, Light W, Wei E. Asbestos: mechanisms of toxicity and carcinogenicity in the respiratory tract. Ann Rev Pharmacol Toxicol 1983; 23:595-615
36 McDonald JC, McDonald AD. Epidemiology of asbestos-related lung cancer. In: Autmank and Aisner, eds. Asbestos-related malignancy. Orlando, Fla: Greve and Stratlon, 1987:57-79
37 Selikoff IJ, Churg J, Hammond EC. Asbestos exposure and neoplasia. JAMA 1964; 188:22-6
38 Alderson M. Occupational cancer. London: Butterworth, 1986: 60-77
39 Morgan RW, Foliart DE, Wong O. Asbestos and gastrointestinal cancer: a review of the literature. West J Med 1985; 143:60-5
40 Edelman DA. Exposure to asbestos and the risk of gastrointestinal cancer: a reassessment. Br J Ind Med 1988; 45:75-82
41 Einterline PE, Hartly J, Henderson V. Asbestos and cancer: a cohort followed up to death. Br J Ind Med 1989; 44:396-401
42 McConnel EE, Rutter HA, Allan BM, Moore JA. Chronic effects of dietary exposure to amosite asbestos and tremolite on F344 rats. Environ Health Perspect 1983; 53:27-44
43 Word JM, Frank AL, Pevor MWD, Tarona RE. Ingested asbestos and intestinal carcinogenesis in F344 rats. J Environ Pathol Toxicol 1980; 3:301-12
44 Linet MS, Stewart WF, Van Natta ML, McCaffrey LD, Szklo M. Comparison of methods for determining occupational exposure in a case-control interview study of chronic lymphocytic leukemia. J Occup Med 1987; 29:136-41
45 Schwartz DA, Vaughan TL, Heyer NJ, Koepsell TD, Lyon JL, Swanson GM, et al. B-cell neoplasmas and occupational asbestos exposure. Am J Ind Med 1988; 14:661-71
46 Kagan E, Jacobson RJ. Lymphoid and plasma cell malignancies: asbestos-related disorders of long latency. Am J Clin Pathol 1983; 80:14-20
47 Blot WJ, Morris LE, Stroube R, Tagnon I, Fraumeni JF. Lung and laryngeal cancers in relation to shipyard employment in coastal Virginia. J Natl Cancer Inst 1980; 65:571-75
48 Dohner VA, Beegle RG, Miller WT. Asbestos exposure and multiple tumors. Am Rev Respir Dis 1975; 112:181-99

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