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Lung Cancer Prevalence Among Shipyard Workers

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The prevalence of lung cancer has been ascertained during a survey of 286 shipyard workers all 20 to 45 years from onset of asbestos exposure in shipyard work. Two men had had previous thoracic surgery for lung cancer. In addition, bronchogenic carcinoma was found in five men. One was among the 35 men less than 30 years in the yard: three were in the 191 who had begun work 30 to 39 years before, and one was in the group of 60 men who were 40– years from onset. The potential usefulness of large-scale surveillance programs for the early detection of lung cancer among current and former shipyard workers is discussed.

Key words: lung cancer, pneumoconiosis, high risk groups, shipyard workers, surveillance programs

INTRODUCTION

A sharp focus was directed to the potential for asbestos-associated neoplasms among shipyard workers in 1968 by the germinal reports of Harries [1968], and Stumphius [1968]. Both reported mesothelioma and noted that the disease seen by them was not among "asbestos workers" but among co-workers in other crafts in the yards. Their observations have been amply confirmed [Selikoff and Hammond, 1978] and asbestos-associated disease among currently employed and formerly employed shipyard workers now constitutes a major public health problem.

Insofar as mesothelioma is concerned, shipyard workers in many other countries have been found to have such disease. The increasing incidence [Sheers and Cole, 1980] is regarded as an index of past exposures during and after World War II [Sheers and Cole, 1980].

Other asbestos-associated disease has been reported, including asbestosis, lung cancer, gastrointestinal and oropharyngeal cancer [Blot et al, 1979]. The wide prevalence of asbestosis among current and former shipyard workers has been extensively reported [Harries et al, 1972; Murphy et al, 1978; Felton, 1979; Polakoff et al, 1979]. Lung cancer has also been reported in excess [Blot et al, 1978] but

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population-based data have so far been scant. There has been much interest in the question of lung cancer among shipyard workers, since, at the least, smoking cessation programs directed to them might diminish the risk [Hammond et al, 1979; Selikoff and Hammond, 1979].

For these reasons, we have sought to obtain information concerning the prevalence of lung cancer among a group of shipyard workers who constituted a group at particularly high risk of this disease, all being 20–45 years from onset of exposure in shipyard work [Selikoff et al, 1980] with known significant incidence of asbestotic radiological changes in the group as a whole [Selikoff et al, 1980].

PRESENT INVESTIGATION

We have investigated workers in a shipyard which has been in operation for more than 50 years, on the East Coast of the United States. The workers there have been represented by their current union from the mid-1930s. All active members on the union's rolls on January 1, 1979, were listed by seniority. From a list of those 20 or more years from onset of employment in the yard, we sought to invite all burners, welders, and painters for examination, as well as every second or third individual in each of the other departments. Preference was given to the selection of burners and welders because of a desire to investigate exposure to metal fumes during welding and cutting operations [Grandjean et al, 1981], and to painters because of their exposure to solvents. The selection in other departments attempted to achieve approximately equal representation by trade. There were a number of departments with only a few workers eligible for inclusion in the study, and as findings in such groups would be difficult to evaluate, men in these departments were not invited (time keeping, fire department, fabrication, blacksmith, coppersmith, tool room, transportation, powerhouse, and dock). Twenty-one eligible individuals worked in these departments, constituting 6 percent of the possible invitees. All these considerations resulted in a total of 179 of 329 eligible currently employed workers being invited to participate.

Retired members, 20 or more years from onset, were then listed alphabetically. All painters and welders were scheduled, followed by every second retiree in the same departments utilized for active employees. With consideration of geographical proximity (within 250 miles), 284 of 490 eligible retired members were invited. The total number of men scheduled was 463. It was our intention to seek both active and retired members of the local, since this would permit access to men with long duration from onset of employment, even if currently retired, to facilitate observation of the longer term effects of shipyard employment. The examinations were accomplished February 24–27, 1979. The participation rate among those invited was gratifyingly high. One hundred thirty-nine of the 179 actively employed and 147 of the retired men who were invited, came for examination. The distributions in age and time from onset of shipyard employment of those examined are shown in Table I. Most participants were between 50 and 69 years of age and had begun work 30 to 39 years previously.

Examination included lifetime occupational and medical histories, with smoking habits, full physical examination, biochemical and hematological studies, full size (14" × 17") chest films, pulmonary function tests, including ventilation and diffusion studies, as well as ear oximetry, and neurobehavioral examinations for solvent toxicity.

TABLE I. Participation in a Health Survey of Shipyard Workers

Department	Eligible men[a]			Participated		
	Active	Retired	Invited[b]	Active	Retired	Total
Burners, welders	79	94	173	59	49	108
Fitters	51	84	73	18	21	39
Pipe shop	17	26	28	7	4	11
Outside machine shop	29	42	16	5	8	13
Riggers	24	49	40	5	19	24
Carpenters	4	27	16	1	10	11
Painters	22	27	49	18	9	27
Laborers	31	44	20	6	7	13
Equipment operators	15	15	13	8	4	12
Inside machinists, boiler, electric and sheet metal shops and maintenance	57	82	35	12	16	28
Total	329	490	463	139	147	286

[a]All more than 20 years from onset of shipyard employment.
[b]In addition, invitations were not provided to 21 active and 65 retired men in the following trades: time keepers, firemen, fabrication shop, blacksmiths, coppersmiths, joiners, toolroom, transportation, powerhouse, dock department.

TABLE II. The Distribution of Small Opacities Among 284 Shipyard Workers

ILO/UC classification small opacities[a] (combined perfusion)	Active			Retired		
	Normal pleura	Abnormal pleura	Total	Normal pleura	Abnormal pleura	Total
0/–	0	0	0	0	0	0
0/0	9	2	11	3	3	6
0/1	12	10	22	15	6	21
1/0	10	13	23	11	12	23
1/1	33	31	64	16	34	50
1/2	5	3	8	2	6	8
2/1	3	1	4	3	10	13
2/2	2	3	5	4	16	20
2/3	0	0	0	0	1	1
3/2	0	0	0	2	0	2
3/3	1	1	2	1	0	1
3/4	0	0	0	0	0	0
	75	64	139	57	88	145

[a]No large rounded opacities were observed.

There was much radiological evidence of asbestosis. Chest films were read by a panel of five experienced physicians using the ILO U/C Classification of Radiographs of Pneumoconioses, without knowledge of the clinical, work history, or other characterization of the individual. Consensus readings were recorded. Of the 286 individuals examined in this survey, interpretable x-rays were obtained for 285.

One individual failed to have an x-ray taken and one had severe sarcoidosis which precluded obtaining information on any pneumoconiosis that might be present. Thus, 284 x-rays were available for analysis.

The distribution of abnormalities, according to the full ILO U/C Classification of Pneumoconioses for small opacities, is shown in Table II. No large opacities were observed. Radiological evidence of pneumoconiosis was found in 86.3% of the workers examined. Thirty-nine of 284 (13.7%) men had normal films. Parenchymal fibrosis alone was found in 90 cases, and 21 had only pleural abnormalities. One hundred thirty-four had both parenchymal and pleural changes. These parenchymal changes were largely classified as small irregular opacities (s) characteristic of effects of asbestos exposure. A small percentage of the x-rays (6.3%) also showed small rounded opacities characteristic for effects of other dust exposures. The abnormalities were generally unequivocal. One hundred fourteen, 40.1% of the entire group, were of category 1/1. More extensive abnormalities were also common, especially among retirees. This would reflect the longer time from onset of exposure among these individuals. The proportion of individuals with abnormal films increased with longer duration from onset of shipyard employment. Among 37 men who were 20 to 29 years from onset, 25 (67.7%) had abnormal films. Of 192 who were 30 to 39 years from onset, 170 (88.5%) were abnormal. Of 55 men 40 or more years from onset of shipyard employment, approximately the same proportion were abnormal (50 men; 90.9%).

Since shipyard workers sometimes work in more than one yard during their working lifetimes, and since work in other yards, with new ship construction, might have had a different effect than that associated solely with ship repair and ship maintenance, we have analyzed the x-ray findings for the 185 men who had been engaged only in shipyard work in the ship repair yard under study for their working lifetimes. The results were almost identical, in terms of proportions of men with the various radiological abnormalities. Further, these findings were present among workers in each of the trades, with no department free from risk.

Cigarette Smoking

Among the men, there were 110 current smokers, 118 ex-smokers and 56 with no history of cigarette smoking.

Asbestos Exposure

Previous studies of shipyard employees have described widespread dissemination of asbestos fibers during routine installation and maintenance of thermal insulation materials aboard ship. In addition to the direct exposure of the workmen involved, indirect exposure can occur to men of many crafts working nearby. From the occupational histories obtained in this survey, it was found that during previous years the opportunity for asbestos exposure to virtually all of the men examined was great. Although only three of the 286 men had worked regularly as insulators, approximately half of the remaining individuals were employed in crafts that occasionally work directly with asbestos material. These included welders; pipefitters; and boilermakers, who occasionally were required to remove small sections of asbestos material from high temperature lines and equipment prior to repair work; carpenters, who cut asbestos cement panels; burners and welders, who occasionally used woven asbestos blankets for heat shielding; and laborers, who

cleaned up asbestos debris. Indirect exposures additionally were common among men of the above trades, as well as among riggers, shipfitters, machinists, painters, and electricians, among others working aboard ship during and after asbestos installation and repair. Even men assigned to yard shops (machine, electrical, sheet metal, etc) go aboard ship at times and may have been previously assigned to shipboard work. Furthermore, asbestos exposures within the shops could also have occurred through the dissemination of the asbestos fibers from elsewhere in the yard or through exposure to asbestos materials within the shop.

Previous X-ray Evidence of Disease

At the time of this survey, the individuals examined were queried as to the results of previous chest x-ray examinations, which had been provided by a variety of health care facilities. Of 282 men, 264 reported having had a previous x-ray and 185 provided information of their understanding of the results of the readings. Of those aware of the results, 38 (20.7%) were told that abnormalities were present on their chest films. For those with x-rays taken during the previous two years this percentage was 26.6% (25 of 97). However, 57 of 81 individuals (70.0%) whose x-rays in this examination were found to be abnormal, and who knew the results of an x-ray taken during the previous two years, were unaware of the presence of any abnormality. This included 15 of 26 individuals with 2/1 or greater profusion of small opacities.

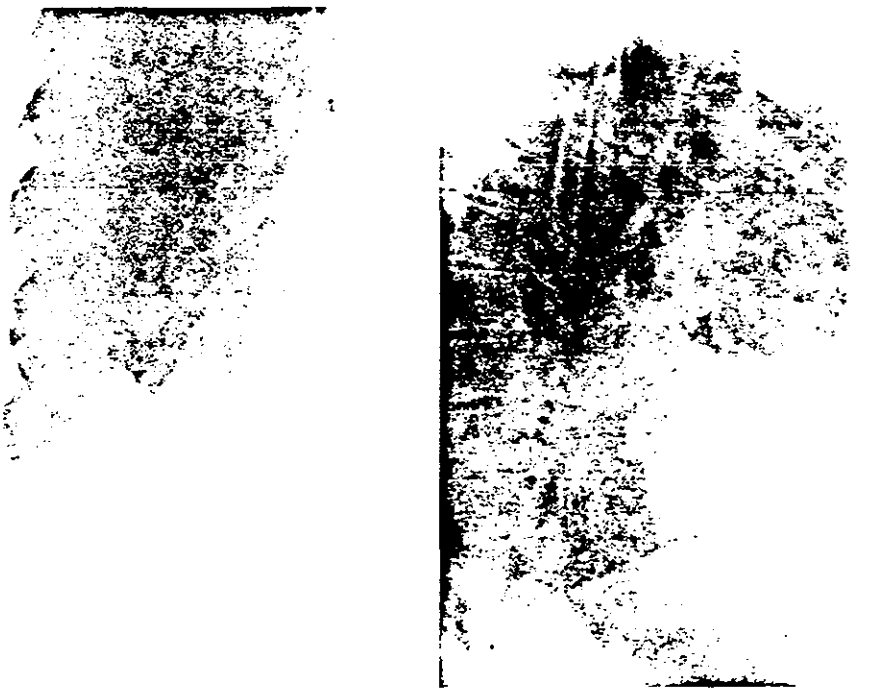
None was aware of the current presence of a potential neoplasm. Two had had previous resection of bronchogenic carcinomas one and six years before (and were found well, without clinical recurrence, at the survey examination).

PREVALENCE OF LUNG CANCER

During the survey, it was found that two men had had previous thoracic surgery (lobectomy, pneumonectomy) for lung cancer. In addition, radiological evidence of probable bronchogenic carcinoma was identified in five men. In each, subsequent study provided histological confirmation of the diagnosis. Table III analyzes the distribution of these five cases among the 286 examined in terms of duration from onset of exposure. All were smokers. It will be seen that there was one case among the 35 men less than 30 years in the yard, three in the 191 who had begun work 30–39 years before and one in the 60 men who were 40+ years from onset. A variety of trades were involved: two were welders, one carpenter, one a machine operator and the last a crane operator.

TABLE III. Lung Cancer Among 286 Shipyard Workers

	Duration from onset of shipyard work (years)	
Number examined		Lung Cancer
35	20–29	1
191	30–39	3
48	40–49	1
12	50+	0
286		5



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Figs. 1 & 2. Case 1. Chest x-ray showed 1/1 reticular fibrosis in the left lower lung field (infiltration could not be evaluated on the right). Some pleural thickening was present (A 1 in the ILO U C Classification). Of particular note, however, was evidence of collapse of the right lower lobe, presumably by an intrabronchial lesion (Figure 1). There was also the suggestion of a lower lobe mass. The lower lobe localization if well seen on the lateral film (Figure 2).

Case Reports

Case 1: This patient was examined on February 27, 1979. He had been born on February 8, 1907 and, after odd jobs, had been a laborer in 1929. He then shoveled coal in a steel company from 1933 to 1940. The patient first went to work at the shipyard on November 28, 1941; he worked as a carpenter and continued until May 1, 1970, when he retired. He considered himself in fairly good health although he was aware of impaired hearing. He had had a heart attack in 1955 and in 1966 had been given medication for possible tuberculosis. His last previous chest film had been made in 1975 and was said to have been normal. He was moderately short of breath with any exertion; he avoided stairs, for example. This had not progressed for more than ten years. It was said to have begun 12 years before, following spontaneous pneumothorax. There was moderate cough and sputum. He had started smoking cigarettes (two packs per day) at the age of 16 and had continued until 1967. He had not smoked since.

Laboratory studies were not remarkable, with normal results for hematological and biochemical examinations. CEA was 1.5 ng/ml (<2.5 ng/ml normal for nonsmokers). Pulmonary function study showed FVC 2.18/1 (predicted 3.96). FEV_1/FVC, 0.28. Chest x-ray showed a mass in the right lower lobe (Figures 1,2),

small opacities in both lung fields (s) 1/1 in the ILO U/C Classification. Rounded opacities were not seen. The left costal pleura was thickened (A/1 in the same classification) and the costophrenic angle on the right was blunted. Bullae were present as was a diaphragmatic plaque. Slight clubbing of the nailbeds was present.

The patient was told of the diagnosis and his personal physician was notified. However, he did not present himself to the hospital until June. A possible reason for the delay in treatment was the fact that the patient's physician died and records were not available: there was delay in obtaining the assistance of another physician. At that time he felt well, was gaining weight and had no new complaints. Vital capacity was 2.24 l (liters) before bronchodilation and 3.32 l afterwards. Predicted was 3.88. FEV_1 was 0.85 l (1.07 after bronchodilation). Residual volume was 1.72 liters predicted, and 5.68 observed. Total lung capacity was 5.60 predicted and 8.82 observed. Diffusing capacity was 15.5 against 24.1 predicted (64%).

Bronchoscopy was done shortly after admission and was interrupted by bleeding following transbronchial biopsy. The sputum, however, was positive for malignant cells consistent with squamous cell carcinoma. It was considered that his pulmonary function status did not permit resectional surgery and radiotherapy was instituted. Unfortunately, this failed to control his disease and he died in September, 1980.

Case 2: This man was examined on February 26, 1979. He had been born on January 10, 1915. His first job, in 1929, was as a grocery store clerk and from 1930 to 1941 he was employed as a machine operator in a book bindery. On February 10, 1941 he began work in the shipyard as a welder with about 75% of his time aboard ship. For the period of approximately 1963 to 1973, he did both welding and burning. He retired on October 1, 1973. When examined, he considered himself reasonably well. His previous medical history included hospitalization for a myocardial infarction in 1973. He was moderately short of breath, not being able to keep up with others of his age walking on level ground. This had first been noted about six years before, and had been gradually progressive, especially in the previous six months. His last chest film had been taken in February of 1976: he was informed that it was normal. At his last physician's visit, for a "routine checkup" a chest x-ray had not been made. There was moderate cough and sputum. He had begun smoking at the age of 14 and was still smoking about two packs a day. Extensive hematological and biochemical studies were done: only the blood glucose was abnormal (198 mg/ml). CEA was 3.8 ng/ml (<5 ng/ml normal for smokers). FVC was 1.82 l (predicted, 4.31): FEV_1/FVC 72%. Chest x-ray showed bilateral lower lung field reticular infiltrations, s 1/1 in the ILO U/C Classification. There was some thickening of the left costal pleura (A/1). However, an infiltration consistent with a possible malignancy was also seen (Figure 3). The patient was notified of this as was his physician and he was referred to hospital for treatment. Unfortunately, he was found to be inoperable. Radiotherapy and chemotherapy were then given but patient's condition deteriorated and he died on June 14, 1980.

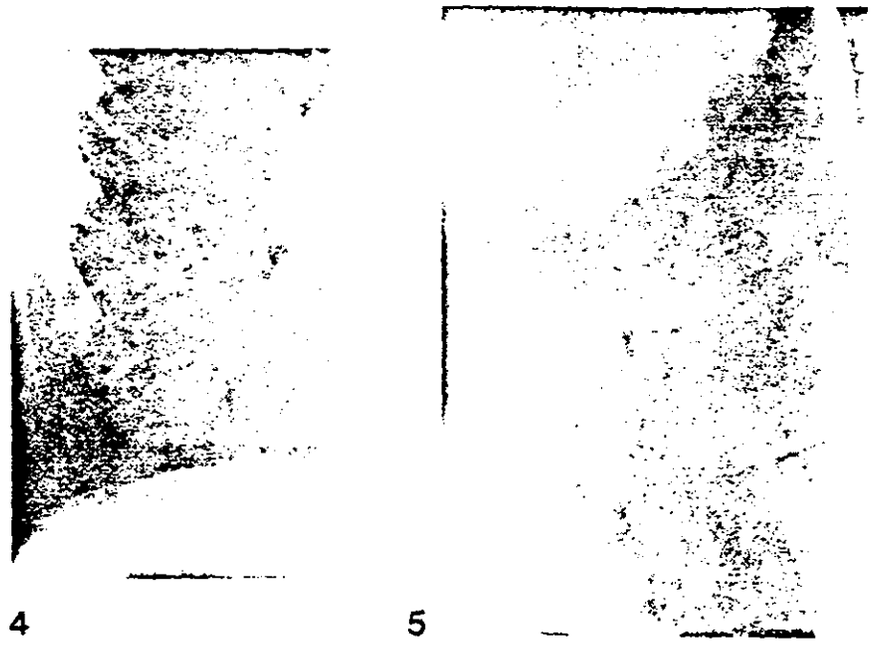
Case 3: This patient was examined on February 25, 1979. He had been born on November 11, 1922. He was first employed in the shipyard on January 7, 1952, and was still employed, as a welder. He was known to have hypertension and was under treatment for this. He had last seen his personal physician earlier in the year. Chest x-ray was not taken. One had been made in 1977, when an infiltrate had been found

Fig. 3. Case 2. There was evidence of minimal infiltrations in the lower lung fields, of limited intensity (1/0 in the ILO U/C Classification). There was minimal pleural thickening of the left costal pleura (A/1 in the same Classification). Bullae were present laterally at left base and there were diminished vascular markings in the upper lobes, consistent with emphysema. A mass was seen in the right mid-lung field with the appearance of bronchogenic carcinoma.

in the right lower lobe. The patient stated he was told that this was a "calcium deposit". The patient was not significantly short of breath. He had begun smoking at the age of 16 and was still smoking 1½–2 packs per day. He did not complain of cough although he did notice phlegm on rising in the morning.

On examination, there was no clubbing of the fingers and chest auscultation showed normal breath sounds. Laboratory studies were not remarkable except for a slight elevated alkaline phosphatase (124 units with 110 as the upper range of normal for this laboratory). CEA assay showed 2.4 ng/ml (normal range less than 5 for smokers). Blood lead was 56 mg/100 ml (normal less than 40 mg). Pulmonary function tests showed FVC 3.78 liters (4.71 predicted). FEV_1/FVC 77%. His chest x-ray was abnormal with 1/1 irregular small opacities (s) in both lower lung fields: some pleural thickening (B/1) was also seen. A plaque was present on the left diaphragm and a nodule was found in the right lower lobe (Figures 4 and 5). The matter was discussed with the patient and his physician. A right lower lobe lobectomy was done, with lung cancer found. The patient was well on January 2, 1981, with no clinical recurrence of the disease.

Case 4: This man was examined on February 26, 1979. Born on March 30, 1913, he had begun work in the shipyard on April 7, 1930, after two years as a helper



Figs. 4 & 5. Case 3. Only limited reticular fibrosis was seen in the lower lobes, categorized in the ILO U/C Classification as 1/1. There was localized pleural thickening in the left mid-costal pleura (A/I in the same Classification), as well as a plaque on the left diaphragm. There was a nodule at the right base, not completely round, suggestive of a bronchogenic carcinoma, and a probable node at the right hilum (Figure 4). The lower lobe localization was well made out, on the right oblique film (Figure 5).

in a tannery and as a machinist helper in a scrapyard. In the shipyard, he continued as a machinist until his retirement on December 1, 1973. In 1933, he worked aboard ship but the rest of the time his work was largely in the machine shop, on land. While much was with turrent lathes, he volunteered that it also required ripping asbestos material from machines.

At the time of examination, he was in reasonably good health although he had hearing loss, cataracts, sinusitis and pain ascribed to osteoarthritis. He had been short of breath on moderate exertion for at least two to three years and had moderate cough and sputum. He had smoked about one pack of cigarettes a day from the age of 14.

Laboratory (hematological, biochemical) tests were not remarkable. CEA was 4.7 ng/ml (normal for cigarette smokers < 5.0 ng/ml). Pulmonary function studies showed FVC to be 2.69 liters (predicted 4.40) and FEV_1/FVC 0.64%. There was no clubbing. Chest film showed bullae and hyperradiolucency but no certain evidence of reticular fibrosis (0/1 in the ILO U/C Classification). However, a lesion was seen in the right upper lobe, suggestive of lung cancer (Figure 6). He and his physician were notified and, on April 12, 1979, a right upper lobe lobectomy was done. Distinct nodules were found, interpreted as two primary lesions. Pathological diagnosis was adeno-squamous bronchogenic carcinoma. The patient was well without recurrence of the neoplasm on January 2, 1981.

Fig. 6. Case 4. The chest film was essentially unremarkable apart from a "smudge" shadow overlying the right seventh posterior rib. The possibility of bronchogenic carcinoma was entertained.

Case 5: This worker was born on February 10, 1915. He was currently employed at the time of his examination on February 26, 1979. Prior to his work at the shipyard, he had done farm work from the age of seven and then forest ranger work. He was first employed at the yard on July 24, 1941, and worked for one year as a rigger. He then became a crane operator on the dock and continued at that from 1942 until the time of examination. When examined, he stated that he was essentially well except for hypertension for which he was being treated by his personal physician. He had smoked more than two packs of cigarettes per day for more than 35 years. He was not short of breath except with strenuous activity.

On examination, no crepitant rales were heard but minimal finger clubbing was noted. Hematological and biochemical studies gave results within normal ranges except for electrolyte variations believed to be associated with long term diuretic therapy. CEA was 6.2 ng/ml (< 5 ng/ml for smokers in the analytical laboratory). FVC was 4.93 liters (predicted 4.38). FEV_1 was 3.42 liters ($FEV_1/FVC = 0.69$). He stated that he had had a chest film in the yard "about two months before" but was not aware of the results.

Chest x-ray showed no interstitial fibrosis or pleural change although some hyperradiolucency was present suggestive of emphysema. In the left upper lobe there was a 1 cm shadow (Figures 7 and 8) interpreted as possible carcinoma. The patient and his physician were immediately notified about this possibility. Admitted to the hospital, a bronchoscopy was done and failed to provide evidence of a

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Figs. 7 & 8. Case 5. The chest x-ray was unremarkable apart from a "smudge" shadow overlying the fifth rib at the posterior angle (Figure 7). The possibility of cancer was considered and tomograms were made. On the 12 cm postero-anterior section, a nodule was found to be present (Figure 8).

neoplasm but left cervical node biopsy showed poorly differentiated adenocarcinoma. CAT scan demonstrated a lesion in the left temporal area of the brain. Anomia appeared and was partly relieved by steroids. This belief was short-lived, however, and despite radiotherapy to the brain the patient became confused and disoriented and died on July 28, 1979.

DISCUSSION

Asbestos is no longer used in the construction of new ships in the United States [Polakoff et al, 1979] although the potential for shipyard asbestos exposure continues in the repair of ships still afloat [Selikoff, Nicholson and Lilis, 1980]. Nevertheless, a major public health difficulty remains: the potential for asbestos-associated disease among the many hundreds of thousands of former and current shipyard workers exposed to the mineral before controls and substitutes were extensively utilized. Approximately 4,500,000 men (and women) worked in shipyards during World War II [Selikoff and Hammond, 1979] and shipyard employment in the postwar period averaged somewhat over 200,000 workers at any one time [Hammond et al, 1979; Selikoff and Hammond, 1979]. We have estimated that approximately 5,000,000 individuals worked in our shipyards 1940–1975. There are relatively few data concerning age distribution of these workers; from that available our best estimate is that about 2,800,000 are presently alive, with about 90% currently 30 or more years from their onset of work experience and asbestos exposure. This group has entered its phase of heightened cancer risk, particularly for lung cancer and mesothelioma, and they will gradually be joined by those currently with lesser latency, well into the twenty-first century.

A significant problem with this high risk group, therefore, is how to minimize that risk. It is appreciated that, at the moment, little can be done in terms of early diagnosis (or effective therapy) for mesothelioma. Whether this is equally true for lung cancer is uncertain. First, there has been much disappointment concerning the cost-effectiveness and therapeutic outcomes in population surveys for lung cancer in general, even among cigarette smokers. The diagnostic yield among apparently well groups has been low in prevalence surveys. Second, those cases which are found—early, in terms of absence of presenting symptoms, albeit not necessarily early in biological terms, in view of the presence of radiologically evident disease—do not necessarily show improved survival rates. Yet early diagnosis and treatment is the best we can do at the moment and with early diagnosis and vigorous therapy, it is possible we can at least double or triple current five year survival rates (from approximately 5% to 15–20%).

These perspectives form a background particularly relevant to shipyard workers and present the public health question of whether large-scale periodic, serial surveillance programs should be initiated for the early detection of lung cancer. The results of the study detailed here provide some guidance but are not definitive. The prevalence of previously undiagnosed lung cancer—5 of 284 shipyard workers x-rayed—was similar to that found in an initial survey of asbestos insulation workers in which 11 lung cancers were found in 392 men 20 or more years from onset of exposure [Selikoff, 1965]. The experiences are limited, however, and any generalizations are presently unwarranted. Too, little can be said about the long-term course: many more observations will be needed. Nevertheless, the findings suggest that additional data should be sought as rapidly as possible in similar high risk groups: 28,500 will give us much better guidance than 284.

Surveillance efforts will do more than that, in all probability. They will expedite programs designed to explain and advocate smoking cessation among those shipyard workers currently smoking. Recent experiences suggest that this can significantly reduce the incidence of lung cancer in asbestos-exposed workers: among asbestos insulation workers more than 20 years from onset of exposure, those who stopped smoking, after 5–10 years, had 1/3 to 1.2 the lung cancer incidence of their colleagues who had continued to smoke [Hammond et al, 1979; Selikoff and Hammond, 1979]. This aspect of surveillance efforts should have at least as much attention and planning as x-ray facilities and techniques.

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