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LUNG CANCER AND MESOTHELIOMA DURING PROSPECTIVE SURVEILLANCE OF 1249 ASBESTOS INSULATION WORKERS, 1963-1974 *

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INTRODUCTION

In 1963, it was found that a large group of asbestos insulation workers in the New York metropolitan area had experienced unusual mortality during 1943-1962.¹ Six hundred and thirty-two men had been on the union's rolls on January 1, 1943. By December 31, 1962, 262 men had died, nine before reaching 20 years on the job. Of those who died after 20 years from first employment, lung cancer was found in marked excess; 6.02 such deaths had been expected, and 42 occurred. In addition, there were several deaths due to pleural or peritoneal mesothelioma and a modest increase in deaths due to gastrointestinal cancer, where 9.71 were expected and 29 were observed. There were 12 deaths due to pulmonary asbestosis (TABLE 1).

TABLE 1

EXPECTED AND OBSERVED DEATHS AMONG 632 ASBESTOS INSULATION WORKERS,
NEW YORK-NEW JERSEY, 20 OR MORE YEARS AFTER ONSET OF WORK,
JANUARY 1, 1943 TO DECEMBER 31, 1962

	Expected *	Observed
Total deaths, all causes	196.16	253
Total cancer, all sites	31.44	95
Lung cancer	6.02	42
Pleural mesothelioma	†	3
Peritoneal mesothelioma	†	1
Cancer of stomach, colon, rectum	9.71	29
All other cancers	15.71	20
Asbestosis	†	12
All other causes	164.72	146

* Nine men died before reaching 20 years from first employment. Expected deaths are based upon white male age-specific death rate data of the U.S. National Office of Vital Statistics from 1949 to 1962. Rates were extrapolated for 1943-1948 from rates for 1949-1955.

† Rates are not available, but these diseases are rare causes of death in the general population.

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A23913

It had previously been established that lung cancer was a formidable hazard of asbestos factory workers² and that termination of employment did not abort the risk; apparently, once sufficient exposure had occurred with continued retention of asbestos within the lung, risk remained. This factor was of considerable concern, because a significant number of men were known to have worked as asbestos insulation workers in the New York metropolitan area, and many were still in the trade. In addition to the 370 survivors of the original 1943 cohort, 890 men had joined the insulation union[†] during the period 1943-1961, and 879 of them were alive on January 1, 1963. Together, the two groups constituted a total of 1249 men who were either working regularly as asbestos insulation workers in 1963 or who had been recorded as having worked regularly at this trade for shorter or longer periods in previous years.

TABLE 2

MEMBERS OF ASBESTOS WORKERS' UNION ON JULY 1, 1963, ADMITTED TO THE UNION BEFORE DECEMBER 31, 1942. CLASSIFICATION BY AGE AND SMOKING HABITS ON OR ABOUT JANUARY 1, 1963

Age (yr)	Total No.	Never Smoked Regularly	Pipe, Cigar Only	Ex-cigarette Smokers*	Current Cigarette Smokers*			
					1-9/ Day	10-19/ Day	20-39/ Day	40+/ Day
35-39	2	1	—	1	—	—	—	—
40-44	13	2	—	2	—	—	5	4
45-49	32	2	1	5	—	—	12	12
50-54	109	12	6	26	3	5	33	24
55-59	60	6	5	16	—	3	20	10
60-64	42	7	4	15	1	—	11	4
65-69	49	6	8	17	—	4	9	5
70-74	38	7	7	12	1	4	4	3
75-79	21	3	7	6	—	1	3	1
80-84	4	2	1	1	—	—	—	—
Total	370	48	39	101	5	17	97	63

* Includes cigarette smokers who also smoked pipes or cigars.

Before 1963, there had been no regular surveillance of these asbestos workers, because they were not aware of their special risk. It was considered that potential benefit might be obtained if a program of regular medical surveillance could be initiated, with special focus on the principal risks that had been identified, namely, bronchogenic carcinoma, pleural and peritoneal mesothelioma, gastrointestinal cancer, and asbestosis. Of these risks, lung cancer took first place. In addition to the risk associated with asbestos exposure, a majority of the men had been regular cigarette smokers (TABLES 2 & 3). Such history, even in the absence of asbestos exposure, carried a lung cancer risk of its own.³ (It was later to be learned that the combination of the two factors, asbestos exposure and cigarette smoking, resulted in many more lung cancers than would be assumed from mere summation of the two effects, with asbestos exposure sharply increasing the lung cancer risk of cigarette smoking.^{4,5})

† International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO, CLC, Locals 12 and 32.

A23914

TABLE 3

MEMBERS OF ASBESTOS WORKERS' UNION ON JULY 1, 1961, ADMITTED TO THE UNION JANUARY 1, 1943 TO DECEMBER 31, 1962.
CLASSIFICATION BY AGE AND SMOKING HABITS ON OR ABOUT JANUARY 1, 1963

Age (yr)	Total No.	Never Smoked Regularly	Pipe, Cigar Only	Ex- cigarette Smokers*	Current Cigarette Smokers			Smoking Habits	
					1-9/Day	10-19/Day	20-39/Day	40+/Day	Not Known
15-19	25	9	0	0	0	4	8	3	1
20-24	118	19	1	7	4	11	54	17	5
25-29	171	38	4	15	1	11	72	22	10
30-34	235	36	9	23	6	19	74	46	22
35-39	151	16	5	24	2	6	45	41	12
40-44	101	3	7	15	3	2	40	26	5
45-49	40	5	1	4	0	3	19	7	1
50-54	20	2	1	1	0	1	6	5	4
55-59	9	1	0	2	1	1	1	3	0
60-64	7	2	0	1	0	1	3	0	0
65-69	0	0	0	0	0	0	0	0	0
70-74	0	0	0	0	0	0	0	0	0
75-79	0	0	0	0	0	0	0	0	0
80-84	0	0	0	0	0	0	0	0	0
Total	879	131	28	92	17	59	322	170	60

A23915

TABLE 4
X-RAY CHANGES IN ASBESTOS INSULATION WORKERS*

Onset of Exposure (yr)	No.	Normal (%)	Abnormal (%)	Asbestosis (grade)		
				1	2	3
40+	121	5.8	94.2	35	51	28
30-39	194	12.9	87.1	102	49	18
20-29	77	27.2	72.8	35	17	4
0-9	346	55.9	44.1	158	0	0
	1117	51.5	48.5	366	126	50

* From Reference 7.

PROSPECTIVE CLINICAL SURVEILLANCE

The program of clinical surveillance that was instituted was based on the realization that the chest x ray offered the best method for early detection of lung cancer then available.⁶ An initial pilot survey had demonstrated that the cooperation of the workers involved could be expected.⁷ Examination facilities, including x-ray equipment, were set up in the union halls to facilitate attendance of the men; it is not known whether equal cooperation would have as readily been achieved had it been necessary to site the survey in hospital-based facilities.

The nature of the disease under surveillance required several modifications in usual chest x-ray survey design. First, it was considered that the standard "yearly" chest film would be inappropriate for many of the group (as it was later to be shown to be inadequate for many other individuals as well⁸). In the preliminary survey, chest x-ray examination had shown that many of the men, especially those with more than 20 years from onset of exposure, already had considerable asbestosis (TABLE 4).⁷ If cancer were found, it would be best to discover it at a stage at which limited resection, as lobectomy or even segmental resection, was possible. Diminished respiratory reserve might make pneumonectomy unavailable, even if the neoplasm was otherwise resectable. Therefore, serial chest x rays were advised at 6-month intervals for workers with more than 20 years from onset of exposure, yearly for those 15-19 years from onset, and every 1-2 years for those with shorter histories of duration from onset. Further, rather than the usual posteroanterior film alone being taken, four films were made at each examination, two in the posteroanterior projection (one with increased penetration) and one in each of the two oblique projections. With x-ray changes of asbestosis predominantly to be seen in the lower lung fields, and with a known predilection for asbestos lung cancer to be found in these areas, it was considered advisable to visualize the lower lung fields as well as possible.

Other studies were simultaneously undertaken. Physical examination, with particular reference to the chest, abdomen, and oropharynx,⁹ was supplemented by careful occupational, clinical, and smoking histories; fingers were examined for clubbing, although it was recognized that this finding would have far less diagnostic utility in the presence of asbestosis than it would for lung cancer in general; urine, hematocrit, and serum for rheumatoid factor¹⁰ were examined, and pulmonary function studies, including FVC and FEV₁, were performed.

A23916

After evaluation of the findings, each man was informed of the results of the examination, and, when requested, a detailed review of the data was sent to the individual's personal physician. Confidentiality of examination results was carefully guarded, with none of the individual findings made known either to the employer or to the union, although statistical summaries of results were made available to both.

In some instances, in which it was difficult for the worker to attend for the examination (some retired and were living in California, Florida, or other distant states, and others were residing up to 150 miles from the unions' headquarters), the worker was encouraged to regularly visit his personal physician for similar examination and to send the films obtained for review. Also, a union health plan included opportunity for regular examination of the worker and his family in a program of general medical surveillance, and the advantages of participation in such surveillance were stressed.

When an abnormality was suspected or found, immediate review with the worker's personal physician was sought, and details were provided. Close cooperation during the ensuing special studies was offered, and, in many instances, the diagnostic and treatment facilities of the Mount Sinai Hospital were requested and utilized.

LUNG CANCER AND MESOTHELIOMA, 1963-1974

From January 1, 1963 to December 31, 1974, 198 of the 370 survivors of the original 1942 cohort died. The distribution of causes of death was very much the same as that in the previous 20 years, but the percentages within each category and the ratios between observed and expected deaths were appreciably altered (TABLE 5). Three factors influenced this change. First, as the indi-

TABLE 5
EXPECTED AND OBSERVED DEATHS AMONG 370 NEW YORK-NEW JERSEY ASBESTOS
INSULATION WORKERS, JANUARY 1, 1963 TO DECEMBER 31, 1974

	Expected *	Observed
Total deaths	109.04	198
Total cancer, all sites	20.58	105
Lung cancer	6.18	47
Pleural mesothelioma	†	7
Peritoneal mesothelioma	†	21
Cancer of stomach	1.17	7
Cancer of colon, rectum	2.75	7
All other cancers	10.48	16
Asbestosis	†	25
All other causes	88.46	68
Number of men		370
Person-years of observation		3075

* Expected deaths are based upon age-specific white male death rate data of the U.S. National Office of Vital Statistics from 1963 to 1973. Rates were extrapolated for 1973-1974 from rates for 1968-1972.

† U.S. death rates not available, but these diseases are rare causes of death in the general population.

A23917

TABLE 6

DEATHS AMONG 879 ASBESTOS INSULATION WORKERS, FIRST REGISTERED IN THE INSULATION WORKERS' UNION JANUARY 1, 1943 TO DECEMBER 31, 1962, DURING JANUARY 1, 1963 TO DECEMBER 31, 1974

		Number of Deaths
Total deaths		54
Total cancer, all sites		18
Lung cancer	9	
Pleural mesothelioma	2	
Peritoneal mesothelioma	1	
Gastrointestinal cancer	3	
All other cancers	3	
Asbestosis		5
All other causes		31

viduals in the cohort aged, the distribution of death by cause would also be expected to change, even in the absence of an occupational disease influence. Second, many of the individuals were still at work in 1963 and continued their employment. The influence of total exposure on mortality would therefore be evident; this factor might be of particular importance among individuals with clinical asbestosis,¹¹ for whom additional dust exposure would be particularly disadvantageous. Third, and perhaps most important, the lapsed period from onset of effective exposure progressively lengthened, with increasing likelihood of clinical onset of malignant disease. Because the periods of clinical latency between onset of exposure and evidence of disease vary among the several neoplastic risks of occupational asbestos exposure, it would be expected that there would be differences in incidence of these neoplasms during the decade of observation. In the event, 47 deaths of lung cancer occurred, while 6.18 had been expected; there were seven instances of pleural mesothelioma and 21 of peritoneal mesothelioma, in addition to 25 deaths due to asbestosis. Also, more deaths due to cancer of the esophagus, stomach, colon, and rectum occurred than were anticipated.

We have not yet analyzed the mortality experience of the 879 workers who first joined the union between 1943 and 1962 and were still alive on January 1, 1963. These men were young, most with considerably less than 20 years from onset of exposure, and their risk of death during 1963-1974 was likely to be limited. Observation showed that 54 deaths occurred, and TABLE 6 provides categorization by cause. Observation of these men continues, and it is anticipated that analysis of their mortality experience by cause, contrasting expected and observed deaths, will be able to be usefully undertaken within the next several years.

OCCURRENCE OF LUNG CANCER AND MESOTHELIOMA

Altogether, 59 instances of bronchogenic carcinoma occurred among the 1249 asbestos insulation workers under our observation in the New York metropolitan area from January 1, 1963 to December 31, 1974. Forty-nine cases occurred among the 370 individuals who had already been members of

A23918

TABLE 7

LUNG CANCER IN NEW YORK-NEW JERSEY ASBESTOS INSULATION WORKERS
JANUARY 1, 1963 TO DECEMBER 31, 1974

	Admitted to Union	
	Before 1943	1943-1962
Number as of January 1, 1963	370	879
Lung cancers to January 31, 1974	49	16
Deaths due to lung cancer	48	9

the Insulation Workers' Union in 1942, and 10 cases occurred among the 879 younger men who first became members of the union at some time from January 1, 1943 to December 31, 1962 (TABLE 7).

Review of the clinical status of these 59 men on January 1, 1975 showed that 57 were dead; two were alive. One, a member of the 1942 cohort, had been found to have a bronchogenic carcinoma during the clinical survey undertaken in 1963. Lobectomy was performed, and observation since has yielded no evidence of recurrence. He still works actively at his trade. The second man joined the union in 1946. In 1972, he suffered hemoptysis, underwent lobectomy, and has remained well. Both men had been regular cigarette smokers; no instance of lung cancer was seen among workers without history of regular smoking. Analysis is now underway to study the causes of this dismal record. It is already evident that the usual causes for failure in the management of bronchogenic carcinoma were also present here; in addition, there were other factors, such as peripheral location of the neoplasm and early pleural involvement, important respiratory insufficiency, and occasional difficulty in radiologic diagnosis due to concomitant pleural and parenchymal asbestosis.

Twenty-eight instances of pleural and peritoneal mesothelioma occurred in the 1942 cohort, and three cases of these diseases occurred in the men who joined the trade more recently. All are dead (TABLE 8). There was no effective therapy available.

TABLE 8

MESOTHELIOMA AMONG NEW YORK-NEW JERSEY ASBESTOS INSULATION WORKERS,
JANUARY 1, 1963 TO DECEMBER 31, 1974

	Admitted to Union	
	Before 1943	1943-1962
Number of men	370	879
Pleural mesothelioma	7	2
Deaths	7	2
Peritoneal mesothelioma	21	1
Deaths	21	1

A23913

SUMMARY AND CONCLUSIONS

Fifty-nine cases of bronchogenic carcinoma were observed among 1249 asbestos insulation workers followed prospectively from January 1, 1963 to December 31, 1974 in the New York metropolitan area. Despite the fact that these men, and their medical attendants, were well aware of their risk of such disease, and despite the availability of a standard program of radiologic and clinical surveillance, 57 of the 59 men died. It is clear that surveillance programs as utilized were insufficient to appreciably improve the prognosis among such individuals. At best, early diagnosis of late disease can be said to have been achieved during the surveillance. Far more effective measures of preclinical diagnosis are needed if anticipated disease in this group at high risk of cancer is to be effectively treated.

The important influence of the lapsed period from onset of exposure was evident. Forty-nine lung cancers occurred among the 370 workers who were in the union in 1942, and 10 lung cancers occurred among the 579 men who first joined the Insulation Workers' Union in the New York metropolitan area during 1943-1962.

Nine cases of pleural mesothelioma and 22 of peritoneal mesothelioma were seen. Effective treatment was absent, and all 31 were dead at the end of the study period. Prospective surveillance with the likelihood of earlier diagnosis failed to appreciably improve prognosis in this disease.

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A23920

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A23921

In the research that led to these data, it was reported that peak exposures could be extremely high. It was not uncommon, for example, for two-to-five-minute concentrations of asbestos to range between 50 f/ml and 100 f/ml during the mixing of cement. This mixing, however, would consume only a few minutes' time and be done perhaps once an hour. Thus, exposures measured during that hour, including the mixing, would seldom average more than 5 f/ml. Similar experiences were subsequently reported by Cooper,²⁰ at Lyon, who stated, "Peak concentrations may be high for brief periods, while time-weighted averages are often deceptively low."

We have direct information on asbestos-fiber concentrations, measured by the currently prescribed analysis procedures during recent years only. Insulation materials have changed from earlier years. Fibrous glass has found extensive use, but work with cork is seldom seen today. Moreover, changes in the asbestos composition of insulation products have taken place. Pipe covering and insulation block may have had twice the asbestos content in past years as they have today. During this period, however, work practices were virtually identical to those of past years, and during the period of these measurements, few controls of significance were in use. Thus, dust concentrations measured under these conditions have relevance for the estimate of levels of past years. Considering the possible doubling of asbestos content of insulation materials, and considering that workers may have used asbestos materials more often in the past than now, the data from these three studies would suggest that the insulators' average exposures in the United States during past years could have ranged from 10 to 15 f/ml.

The only early research of note on asbestos-dust concentrations in past insulation work is the 1945 study of Fleischer and his colleagues,²¹ who reported asbestos dust levels during insulation application in four United States shipyards. In this study, dust concentrations were assessed with use of a konimeter (an instrument widely used at that time, but no longer employed), and both total dust and fiber levels were recorded. The study is difficult to evaluate, since the average dust levels reported in different shipyards varied by nearly 100 times. In two yards, average dust concentrations of about 1 f/ml were found; in a third yard, 90 f/ml; and in the fourth, 35 f/ml. During 1965 and 1966, the fourth yard was resurveyed by personnel of the Department of Industrial Hygiene, Harvard School of Public Health.²² In the resurvey, a time-weighted average exposure of about 8 f/ml was determined.

These fiber counts represent all fibers visible in the field of view of a konimeter. Fibers perhaps as short as 1.5 μ would be enumerated. Supplementary data²³ on the size distribution of amosite aerosols in shipyards suggest that this overestimates the number of fibers longer than 5 μ by a factor of two. If we take this factor into account, and simply average the data from the four shipyards studied by Fleischer in 1945, an estimate of from 15 to 20 f/ml is obtained for average asbestos concentrations in insulation work during this period. Similar considerations would yield a value of 4 f/ml for the shipyard survey by Murphy in 1965. It must be emphasized, however, that averages are highly subjective and depend strongly on the vagaries of the particular work practices selected for sampling and the conditions present at that time.

These summaries of asbestos concentrations from 1945 through 1971 by five different research groups in two countries are summarized in TABLE 7. The estimate of from 10 to 15 f/ml for past insulators' average asbestos exposures

A23922