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Disability Compensation for Asbestos-Associated Disease in the United States

Mount Sinai School of Medicine
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DISABILITY COMPENSATION FOR ASBESTOS-ASSOCIATED DISEASE IN THE UNITED STATES

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16. Abstract (Limit: 200 words)

This report describes and analyzes disability compensation experiences resulting from occupational disease caused by asbestos exposure. Six major issues are stressed:

1. Clinical and epidemiological information reviewing the relation of asbestos exposure to human disease;

2. Estimates of the number of workers who were exposed to asbestos in relation to their work 1940-1980, and the proportion who may be expected to develop occupational asbestos disease in the future;

3. Criteria for the diagnosis of asbestos-associated disease;

4. Adequacy of workers' compensation and other types of public and private compensation programs in providing income benefits to those who suffer occupational asbestos disease;

5. Tort litigation against manufacturers of asbestos products.

6. Economic costs to society and to workers and their kin resulting from disability and premature death of workers caused by asbestosis, lung cancer and mesothelioma and other cancers attributable to occupational exposure to asbestos.

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Cancer from occupational asbestos exposure: projections 1965-2030

In recent years, considerable data have accumulated that allow estimates to be made of the cancer mortality associated with past exposure to asbestos. These include new information on the dose- and time- dependence of asbestos-related cancers in various occupational circumstances, an increased awareness of the various trades in which possible asbestos exposure occurred in past years, as well as information on the absolute and relative exposures of these different occupational groups. While the relevant data are less complete than desired, they are sufficient to allow estimates of future asbestos-related mortality to be made. These may be useful in directing priorities for appropriate surveillance and interventive activities that might be undertaken.

The spectrum of asbestos-related cancer

The spectrum of malignant disease that occurs from asbestos exposure is best seen in data from the mortality study of Selikoff et al.[76] on 17,800 insulation worker. This information is shown in Table 2-19 in which the numbers of deaths, by cause, over a ten-year period, are tabulated along with those expected from national rates. Causes of death are characterized both according to those listed on the certificates of death (DC) and according to the best evidence (BE) available from a review of autopsy protocols, medical records, and pathological specimens. For most causes of death the agreement is relatively good, but for mesothelioma and asbestosis considerable differences exist. Because deaths from these causes are rare in the absence of asbestos exposure, their misdiagnosis has little effect upon general population rates. However, as they are common causes of death among asbestos-exposed workers, their misdiagnosis can seriously affect determination of asbestos mortality. Thus the "best evidence" mortality will be used for the estimate of asbestos-related cancers. However, as we will attribute all excess cancer among insulators to their asbestos exposure (see below), the overall results will not differ greatly from that using certificate of death diagnosis. Higher rates of death at one site (as mesothelioma) will be balanced by lower rates at another (as pancreas).

In addition to mesothelioma and cancer of the lung, cancer of the stomach, colon, rectum, esophagus, larynx, pharyx and buccal cavity and kidney are each elevated significantly compared to rates expected for these sites in the general population. (This group will be referred to subsequently as "asbestos-related" malignancies.) Opportunity for fiber contact with the epithelial surfaces of the lung and gastrointestinal tract is clearly evident. Exposure to the mesothelial tissue and kidney can occur as fibers readily penetrate into lung lymphatics and reach the pleural mesothelium ("pleural drift") or can be transported to the kidney or peritoneal mesothelium. Similarly, fiber dissemination occurs to other extrapulmonary organs, such as brain, liver, spleen, etc.[44]). While excesses at these other sites are not of "statistical significance" for individual malignancies, the category, "all other cancers," is elevated at a high level of significance ($p<0.0001$) and we will attribute these excess malignancies to asbestos exposure as well. Their contribution accounts for less than 8% of the total excess cancer compared to the contribution of lung cancer, 56%; mesothelioma, 26%; and the other above specified "asbestos-related tumors", 10%.

The time course of asbestos-related cancer

The time course of asbestos-related mortality from bronchogenic carcinoma is shown in Figure 2-1 according to ages for individuals exposed initially between ages 15 and 24, and 25 through 34. As can be seen, the two curves of relative risk, according to age, rise with the same slope and are separated by approximately ten years. This suggests that the relative risk of developing lung cancer is independent of age and of the pre-existing risk at the time of exposure. In contrast, had one plotted the added risk of cancer, the slope and the amount for group first exposed at older ages would have been two to four times greater than for those exposed at younger ages. If one combines these data and plots them according to time from onset of exposure, the curve of Figure 2-2 is obtained. A linear increase with time from onset of exposure is seen for 35 to 40 years (to about the time when many insulators terminate employment). After 40 years the relative risk falls significantly, rather than remaining constant after cessation of exposure as might be expected from the linear increase with continued exposure. The decrease is not the result of the elimination of smokers from the population under observation as a similar rise and fall occurs for those individuals who were smokers in 1967. (In calculating the relative risk of lung cancer in smokers, smoking specific data from the American Cancer Society study of one million people were utilized.[30]) Selection processes, such as differing exposure patterns or differing individual biological susceptibilities may play a role, but the exact explanation for the effect is not understood. It is, however, a general phenomenon seen in many mortality studies.

The early portion of the curve of Figure 2-2 is remarkable in two aspects. Firstly, it shows a linear increase in the relative risk of lung cancer according to time from onset of exposure. This suggests that the dose of asbestos received in a given period of time increases the risk of cancer by an amount that is proportional to that which existed in the absence of exposure. This increased <u>relative risk</u> is proportional to the dose of inhaled asbestos, which in turn is proportional to the time worked. Thus, the linear rise in Figure 2-2. However, the linear rise can occur only if the increased relative risk that is created by a given dose of asbestos continues to multiply the "background" risk for several decades (at least until age 60), even though the "background" risk will increase by ten- or twentyfold in 30 years. Secondly, the extrapolated line through the observed data points crosses the line of relative risk equal to one (that expected in an unexposed population) very close to the onset of exposure. At most, the line might be adjusted so that it passes through the relative risk of one line at a time from onset of exposure of about ten years. (Note that we are plotting the relative risk of death. Irreversible malignancy would have been initiated several years earlier, since usually one or two years elapse between identification of lung cancer and death and it is likely that a malignant growth was present, unseen, for at least one or two years before becoming clinically evident.) This means that an increased relative risk appropriate to a given exposure is achieved very shortly after the exposure takes place. However, if there is a low risk in the absence of asbestos exposure, as in young workers, cancers that will arise from that increased relative risk may not be seen for many years or even decades until the background risk becomes significantly greater.

The same two points, 1) that the effect of an exposure to asbestos is to multiply the pre-existing risk of cancer in the exposed population and, 2) that the multiplied risk becomes manifest in a relatively short time, can also be seen in the mortality from lung cancer in a study of Seidman et al.[23] Figure 2-3 depicts the time course of the mortality from lung cancer of a group (UNARCO) exposed for short periods of time, beginning five years after onset of exposure. As 77% were employed for less than two years, exposure largely ceased prior to the follow-up period. As can be seen, a rise to a significantly elevated relative risk occurs within ten years, and then that increased relative risk remains constant throughout the observation period of the study. Furthermore, the <u>relative</u> risk from a specific exposure is independent of the age at which the exposure began. This is seen in Table 2-20 where the relative risk of death for lung cancer for individuals exposed for less than and greater than nine months is listed according to the age at entrance into a ten year observation period. Within a given age category, the relative risk is similar in different decades of observation, as we saw before in Figure 2-3 with the overall data. However, the relative risk also is independent of the age decade at entry into a ten-year observation period. (See lines labelled "All" in each exposure category.) There is some reduction in the oldest groups. This can be attributed to the same effects manifest at older ages in insulators or to relatively fewer cigarette smokers that might be present in the 50-59 year observation groups because of selective mortality.

In the calculation of asbestos-related cancer, the time course of non-mesothelial cancer will be treated as follows. The increase in the relative risk of lung cancer will begin 7.5 years after onset of exposure and increase linearly, following the line of Figure 2-2, for the number of years a specified group is employed. After a period equal to the average duration of employment, the relative risk will remain constant until 40 years from onset of exposure, after which it will linearly decrease to one over the subsequent three decades. The magnitude of the increase will be equal to that of Figure 2-2 for insulators and factory employees. The rate of increase for other groups will be proportional to their estimated exposure relative to that of insulators. The same time course will be used for all other non-mesothelial tumors with the magnitude of the increase in insulators being adjusted by the observed frequency of these tumors compared to that expected and that of other groups by their estimated exposure relative to insulators as well.

The treatment of the time-course of mesothelioma differs from that of lung cancer and other malignancies in that there is no background rate in the absence of asbestos exposure with which to compare the asbestos-related risk. Thus, it is necessary to utilize absolute risks of death. Figure 2-4 shows the risk of death of mesothelioma according to age for individuals exposed first between ages 15 and 24 and between ages 25 and 34 as in Figure 2-1. As can be seen, these data, while somewhat uncertain because of small numbers, roughly parallel one another by ten years as did the increased relative risk curves for lung cancer. Thus, the absolute risk of death from mesothelioma appears to be directly related to onset of exposure and is independent of the age at which the exposure occurs. The risk of death from mesothelioma among the insulation workers is plotted according to time from onset of exposure on the right side of Figure 2-4. It increases as the fourth or fifth power of time from onset of exposure for about 40 or 50 years. Thereafter data are scanty and information on the time course is not reliable. For the purposes of analyzing the mortality experience among various groups of workers the relationship depicted in

Figure 2.4 will be used. After 45 years from onset of exposure we will consider the risk of death from mesothelioma to remain constant at 1.2 per 100 person-years for insulation workers employed for 25 or more years. For insulators employed for shorter periods, the risk will be reduced by the fraction of 25 years worked. For other exposed groups the risks depicted in Figure 2-4 will be reduced by the relative exposure of the group compared to insulators and by the fraction of 25 years that a population is exposed.

Dose-response relationships for asbestos-related cancer

Four recent studies have demonstrated that the risk of lung cancer increases linearly with dose over a fairly wide range of exposures. (See Chapter 3)[21,34,48,73] Unfortunately, the studies are not directly comparable. For three, the measure of dose was the exposure to asbestos and other dusts in terms of millions of particles per cubic foot (mppcf) times the duration of exposure. This exposure categorization is highly dependent upon the proportion of nonfibrous material in the aerosol being considered. Some relationships between particle counts and fiber concentrations in fibers longer than 5 micrometers per milliliter (f/ml) have been provided in the literature, but these are tenuous at best, based as they are upon a limited number of observations. Further, the study of Henderson and Enterline[34] was limited to retirees over age 64 of a major asbestos products manufacturer in the United States. As was seen in Figure 2-2, observations of exposed groups begun late in life can differ considerably from those in which follow-up starts at younger years (as, for example, at age 40-45, 20 years after onset of employment). In the fourth study, that of Seidman et al.[73] exposure characterization involved the use of data from plants other than that in which the mortality experience occurred. A discussion of some of the differences of the slopes of the dose-response functions obtained in these studies has been made in Chapter 3. The important aspect is the linearity of effect with increasing amounts of asbestos inhaled.

In the analysis which follows, it is not necessary that one fully understand the reasons for the differences in the slopes of dose-response relationships in mining and various manufacturing operations as the relative risks in different industries will be based largely upon the observed mortality experience in those industries or upon a comparison of the number of cases of mesothelioma or excess lung cancers in different work activities. In this subsequent comparison, however, we will utilize a linear dose-response relationship to adjust for different periods of employment. While the evidence of linearity is strong for lung cancer, we will assume that it also obtains for mesothelioma and other malignancies. The evidence for this is more limited, but an analysis of the risks of mesothelioma according to time of employment in the study of Seidman et al. would suggest that it is true for that tumor as well. For example, 0 of 215 deaths from mesothelioma occurred from less than 6 months exposure, 3 of 82 from 6-11 months exposure, 4 of 74 from 1-2 years exposure, and 7 of 63 from more than 2 years exposure.

Calculation of asbestos-related mortality

As discussed previously, for those trades in which workers have possible asbestos exposure, estimates were made of the number of employees potentially at risk, the relative exposure of those workers compared to insulators, the average employment time of individuals entering a particular trade or industry, and the age distribution of new hires in the various trades or industries. The asbestos-related cancer mortality was calculated as follows. For those employees entering a trade subsequent to 1940, the above data from Table 2-12 were utilized to obtain the number of new entrants into an industry during different periods of time. The age distribution of new manufacturing employees of 1960 (Table 2-21) was used to calculate age-related mortality of new entrants into a trade or industry. This distribution also was found in new hires during 1974 at a major northeast U.S. shipyard (E. Christian, pers. comm.). For each quinquennium at entry, the appropriate age, calendar year, and asbestos risk specific rates were applied to calculate the excess lung and other cancer mortality, the risk of death from mesothelioma, the total mortality (based on U.S. national rates for the entry quinquennium and all subsequent quenquennia until the year 2030 (assuming 1975-1979 rates to apply to the year 2030). This was done for each five-year quinquennium of entry, 1940-1980, and the calculated numbers summed for each calendar quinquennium, 1940-2030. For those employed in 1940, the appropriate age distribution for an industry or trade in 1940, as given by the U.S. Census, was used. For those employed in 1940, it was assumed that onset of asbestos exposure occurred at age 22.5 or 1930 for those 32.5 years or older in 1940.

The excess, non-mesothelial cancer mortality was calculated using the time dependence displayed in Figure 2-2 with the assumption that the manifestation of risk from a given exposure will first take place 7.5 years after its occurrence and increases linearly until 7.5 years after cessation of exposure. The risks of death from mesothelioma were calculated using the data of Figure 2-4, adjusted for each industrial group, with risk assumed to be constant after 45 years from first exposure. Account was taken of the different periods of exposure for each group in each decade, as indicated in Table 2-13. Calculations were made using U.S. white male rates. Some blacks and some women would have been employed in the industries under consideration, although their numbers would have been small. Were data available on the number of blacks and women the use of black male rates would have increased the number of non-mesothelioma cancers and the female rates would have decreased the number, resulting in only a small change from these data.

The results of such calculations are shown in Table 2-22 and 2-25 which list the average annual excess number of lung cancers, mesotheliomas, gastrointestinal and other asbestos-related cancers, and total excess cancer attributable to asbestos exposure in each quinquennium from 1965 to 2030 for the populations in Table 2-12. As can be seen, the dominant contributors to the asbestos-related disease are the shipbuilding and construction industries. Industries directly involved in the manufacturing of asbestos products or with the application of insulation material, contribute a significantly smaller proportion to current asbestos disease and that to be expected for the next two decades.*

It is instructive to look at a display of the number of mesotheliomas and asbestos-related cancers in the shipbuilding industry from the year 1940 to the year 2000. While the total number of malignancies are necessarily uncertain, the data on the time-course of the cancers that will occur are relatively good. These data are shown in Figures 2-5 and 2-6 for the populations first employed prior to 1940, during World War II, and subsequent to 1945. As can be seen, the relative importance of the wartime and postwar exposures are roughly equal, even though a considerably greater number of individuals were employed in World War II. This, of course, occurs because of the relatively short periods of work for the wartime group. Further, while the exposures in the construction industry are more uncertain, the important disease experience is also ahead of us in that industry, largely because of the extensive use of asbestos in spray fireproofing materials between 1958 and 1972. A measure of the overall future disease experience can be seen in Figure 2-7 which depicts the projected annual mesothelioma deaths from 1940 to the year 2000. Of all mesotheliomas that are

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*A preliminary report on this research has been presented elsewhere (W.J. Nicholson, G. Perkel, I.J. Selikoff and H. Seidman. Cancer from occupational asbestos exposure: projections 1980-2000. Banbury Report 9, Cold Spring Harbor Laboratory, pp. 87-111, 1981). In that publication an estimate was presented of the population at risk from asbestos exposure since 1940 (13,200,000) and projections of asbestos-related mortality (8770 deaths in 1982 to 9750 in 1990). The estimates of the population exposed to asbestos presented there, however, did not fully account for the extremely high turnover in workplace employment that we have discussed here. However, as the mortality estimates did not depend on the total population exposed, they are virtually identical to those presented here.

estimated to occur between the years 1940 and 2000, about one-third have occurred to date.

The number of mesotheliomas estimated by this procedure is approximately 40% greater than those that would be estimated to occur nationwide using data of the SEER program for white males during 1978.[18a] Here, initial data (with one center not analyzed) report 98 mesothelioma deaths in 9 of the 10 SEER areas. As they represent approximately a 10% sample of the U.S. population, the national estimate of cases for 1978 would exceed 1000. This is to be compared with our estimate of 1400 for the quinquennium 1976-1980 (and for the year 1978). In this comparison, however, it should be noted that the information used for the estimate of asbestos-related cancers in this work relied upon data that identified asbestos malignancy following analysis of all medical evidence and after a review of all pathological material available. The SEER program, on the other hand, used records-based reports with no review of pathological material. Experience has shown that pathological review will identify as mesothelioma many neoplasms initially categorized otherwise.[46] Further, while well representing the shipbuilding industry, the ten SEER areas underrepresent industrial areas and metropolitan regions which would have had significant construction activities 30 or more years ago. Thus, it is not unexpected that actual U.S. rates may exceed those estimated from the SEER program.

There is observational evidence to support the analytical approach used in these calculations. The data for insulation workers suggest that 650 mesotheliomas and 2,300 excess lung cancers would occur between 1967 and 1976 among members of this craft. This is to be compared with 175 mesotheliomas and 380 excess lung cancers seen among insulators in the single union (The International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO) studied by Selikoff et al.[78] The ratios of 0.27 and 0.17 for the number of deaths among Asbestos Workers Union members to those calculated here is in reasonable agreement with the fraction of all insulators that the union has organized (0.29). The difference in lung cancer and mesothelioma ratios can be attributed to the fact that the insulators organized by this union are older than the entire group estimated to be at risk from 1967 through 1976 and, thus, have a proportionally greater risk of death from mesothelioma than from lung cancer compared to other insulators. Forty-two percent of the Asbestos Workers Union members were 45 years of age or older at the midpoint of the Selikoff et al. study. A comparison of the ratios of the calculated 1977 mesothelioma deaths from industries (Table 2-23) with those observed in the study of McDonald and McDonald (Table 2-15) also shows reasonable agreement.

As discussed previously, one-third of those estimated to have had a potential exposure to asbestos were exposed for only a short period of time and were believed to have a risk less than that equivalent to that from employment in an asbestos products plant or as an insulator for two months. By calculating the person-years of exposure of the "lower risk population" and comparing the result to the total person-years of employment in each industry the contribution of the lower risk group to the estimated excess mortality can be obtained. These results are shown in Table 2-26 and indicate that 32% of the exposed group will contribute less than 2% of the excess, asbestos-related deaths. The numbers are approximate because of uncertainties in the assumed short-term separating rate. They do, however, dramatize the consequences of inclusion of lower exposed individuals in the population at risk.

Asbestosis deaths

The above estimates are of deaths from malignancy. There will be additional deaths from asbestosis that will occur in individuals exposed to high concentrations over long periods of time. In contrast to the asbestos cancers, deaths from asbestosis generally require considerable fiber exposure. They will largely occur in insulators, manufacturing workers and long-term shipyard employees. They will be fewer than the number of mesothelioma deaths among insulators (perhaps one-half to three-fourths). Because of the high labor turnover in manufacturing we would estimate that about one-third as many deaths will occur from asbestosis as from mesothelioma. A similar ratio is probably appropriate for pre- and post-World War II shipyard workers (short-term wartime work would carry only a limited risk of death from asbestosis). Thus approximately 200 deaths annually are now occurring from asbestosis (the condition, however, will be contributory to many more deaths). This number will perhaps double during the next two decades and decline thereafter.

Comparison with other studies

Some previous estimates of asbestos-related mortality exceed those discussed here. In the Department of Health, Education and Welfare estimate that 13-18% of all cancers in the near future will be asbestos-related, recognition was taken that a large number of individuals potentially were exposed to asbestos, their estimate being 8-11 million compared to ours of 27.5 million, 18.8 million of whom had exposures greater than 2-3 f-yr/ml.[22] However, their estimates of the number of "heavily exposed individuals" was subjective and no explicit adjustment was made for the different employment periods of exposed groups. The estimates by Hogan and Hoel[38] that up to 12,000 deaths may occur annually from asbestos cancer placed great emphasis upon possible effects from the shipbuilding industry. They, too, ~~subjectively estimated the number of~~ "heavily exposed individuals" in this trade and did not explicitly account for variations in employment time and may have overestimated the asbestos-related mortality. However, their estimates of the effect of other industries neglected large numbers of individuals with potential exposure. Thus, their estimates for other than shipbuilding would appear to understate the asbestos disease potential.[64] Finally, Blot estimates that 120,000 lung cancer deaths will occur (over the population lifetime) from wartime shipyard employment.[6] Our estimate is 25,000. The difference lies largely in our assigning a much lower risk to the very short term (< 1 year) employees.

A lower estimate of 4,000 asbestos cancers annually has been made by Higginson et al.[34] based upon mid-1970 SEER data for mesothelioma and a multiplier of three for other cancer. However, the multiplier depends on time from onset of exposure and population age and exceeded four during the 1970's. (Compare Tables 2-22 and 2-23). Further, the previously mentioned limitations of the SEER data apply here. Enterline has also estimated that approximately 4,000 deaths will occur annually.[22] He attributes 530 lung cancer deaths/yr to primary manufacturing and insulation work, 900 to secondary, 421 to shipyard employment, 212 to auto maintenance, and 438 for other occupations. In addition to lung cancer, he estimates 1,250 other cancers and 333 mesotheliomas will be asbestos-related. The values for primary manufacturing, insulation work, and auto maintenance are similar to than our estimates and that for secondary manufacturing considerably more. However, much lower estimates are given for shipbuilding, construction and other trades. This is in contrast with the finding that a much greater number of mesotheliomas occur in these trades compared to manufacturing and insulation work.[55]

Expected mortality in asbestos-exposed workers

Tables 2-22 through 2-25 list the projections for the excess mortality associated with past asbestos exposures. For a given work category, these excess deaths will add to those expected in the absence of exposure but, with the exception of mesothelioma, an "excess" death cannot be dististinguished from an "expected" one. As each of these deaths may lead to a claim for compensation or a third party suit, the potential of such cases can greatly exceed the number of excess deaths calculated above. For the heavily exposed (insulators, for example), where the "excess" deaths exceed those expected, the problem is not a great one. However, for groups with lesser exposure, the total number of lung cancer deaths that could be asbestos-related is very much greater than the numbers in Table 2-22. Table 2-27 lists the expected lung cancer deaths over the years 1965-2030 (assuming 1978 rates for subsequent years). As can be seen, the expected numbers exceed the excess by nearly six times. Even if the 32% of individuals with lower exposure are excluded from consideration, the ratios of expected to excess range from 0.4 to 11.7.

Summary and Conclusion

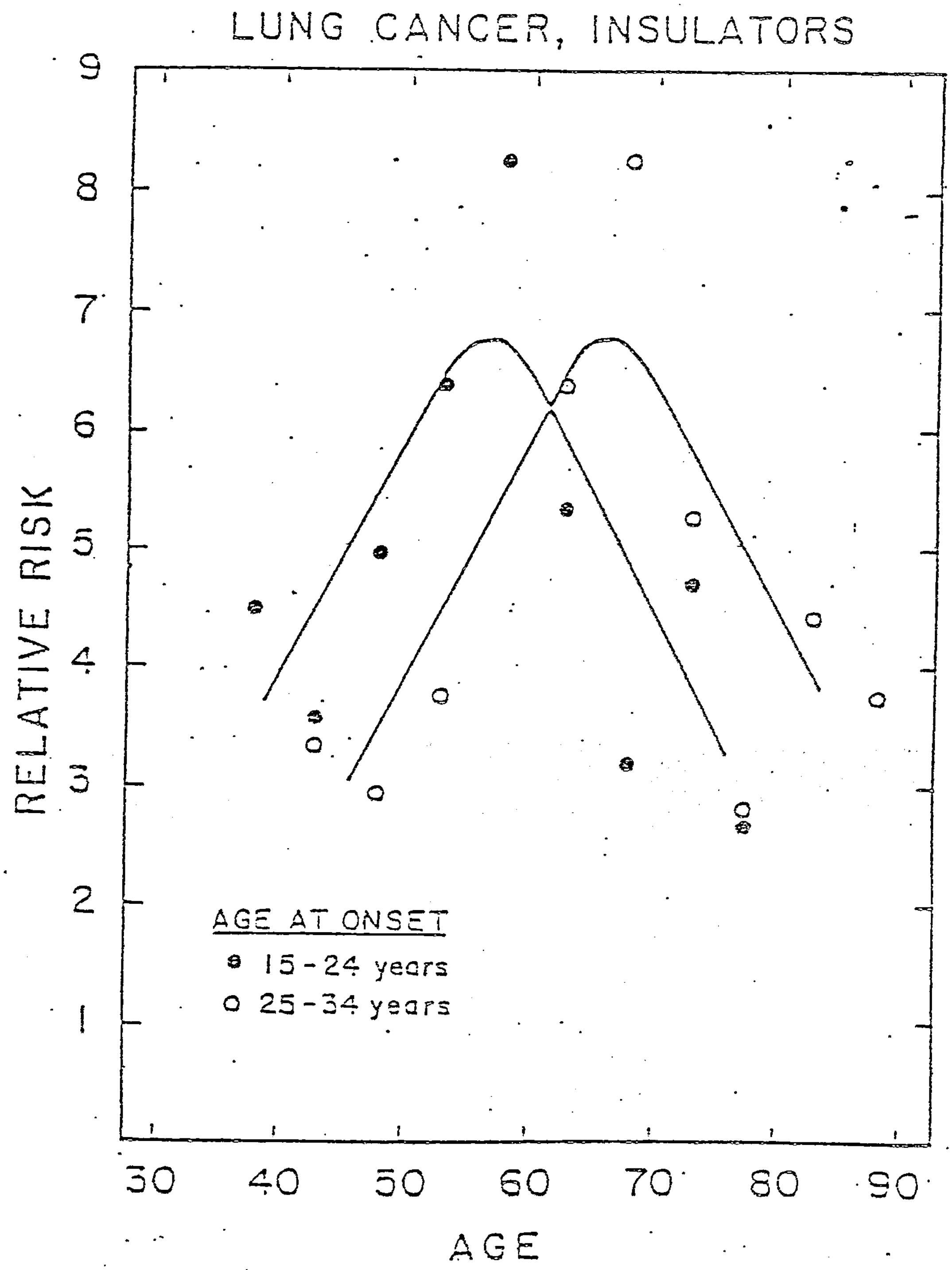
Estimates have been made of the numbers of cancers that are projected to result from past exposures to asbestos in a number of occupations and industries. Only those potentially exposed by virtue of their employment have been considered. Additional deaths will result from exposure among family contacts (household contamination), from environmental exposures, from exposure during consumer use of asbestos products, and from exposure while in the Armed Forces, particularly in engine rooms of naval ships. No estimates have been made of deaths resulting from asbestosis. These estimates indicate that:

1. From 1940 through 1979, 27,500,000 individuals had potential asbestos exposure at work. Of these, 18,800,000 had exposure in excess of that equivalent to two months employment in primary manufacturing or as an insulator (>2-3 f-yr/ml). 21,000,000 of the 27,500,000 and 14,100,000 of the 18,800,000 are estimated to have been alive on January 1, 1980.

2. Approximately 8,200 asbestos-related cancer deaths are currently occurring annually. This will rise to about 9,700 annually by the year 2000.

3. Thereafter, the mortality rate from past exposure will decrease, but still remain substantial for another three decades.

These projections are from past exposures to asbestos. Over one million tons of <u>friable</u> asbestos material are in place in buildings, ships, factories, refineries, power plants, and other facil-



The ratio of observed to expected deaths from lung cancer among insulation workmen according to age and age at onset of employment.

Figure 2-1

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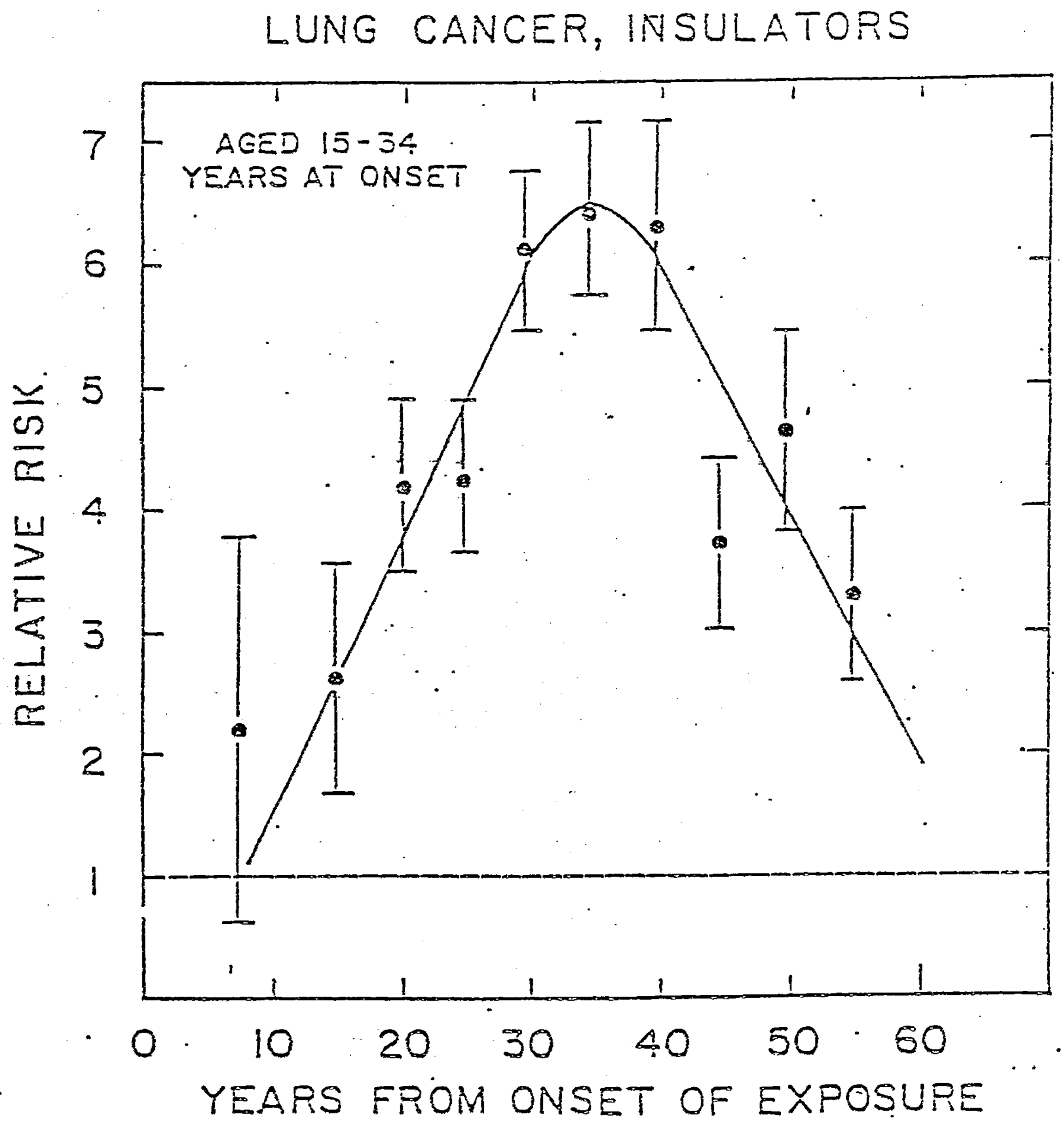
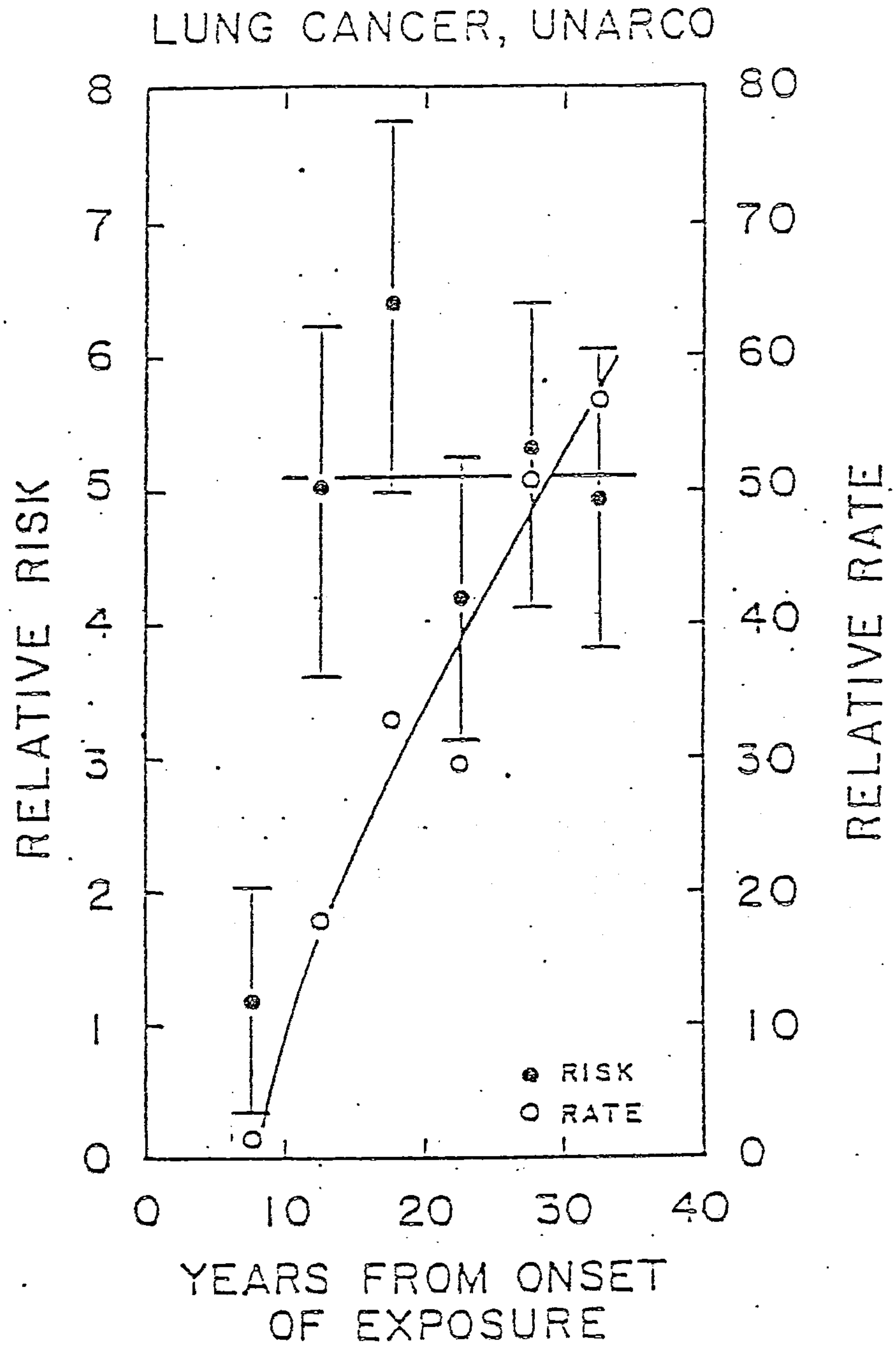


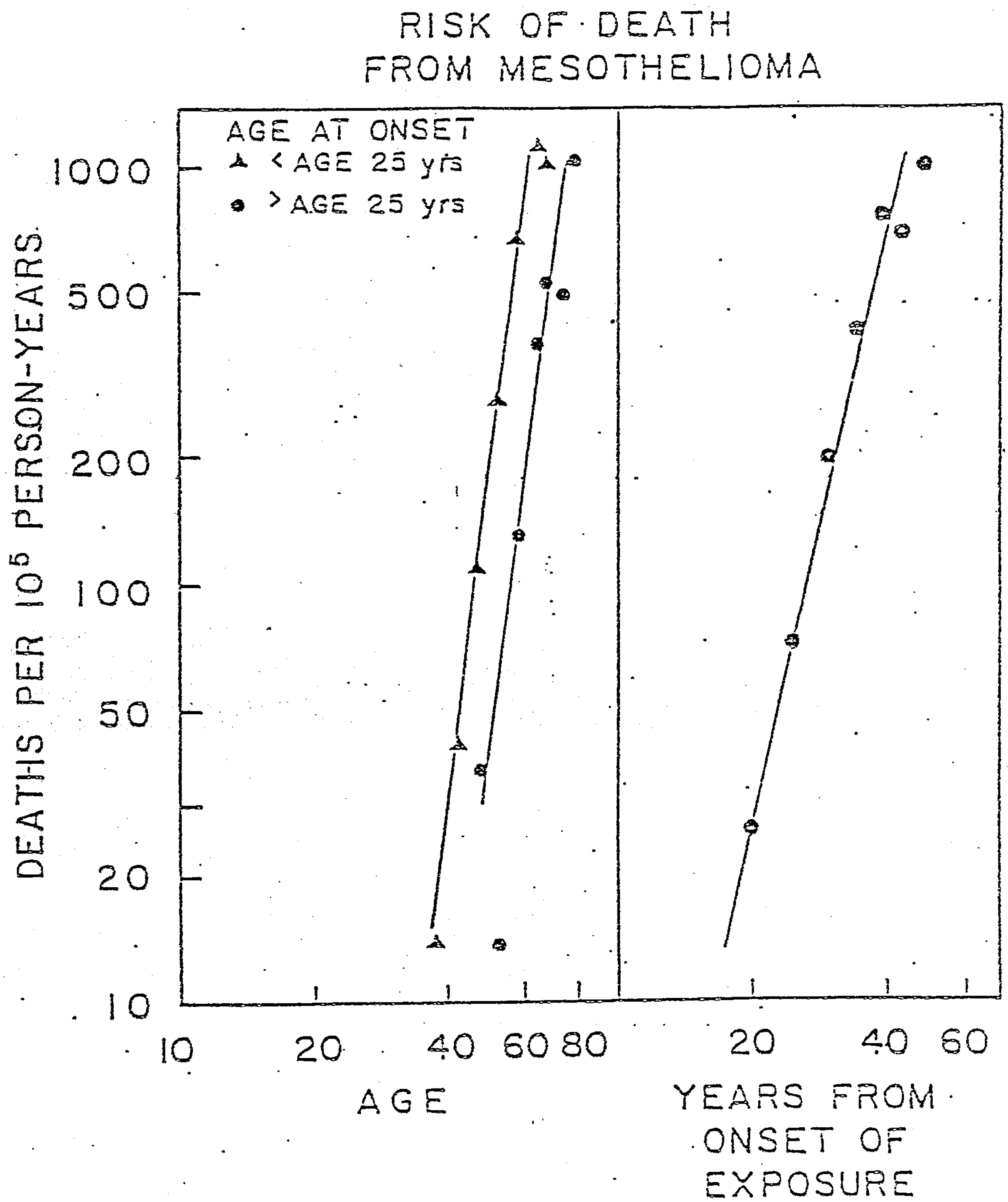
The ratio of observed to expected deaths from lung cancer among insulation workmen according to time from onset of employment.

Figure 2-2



The ratio of observed to expected deaths from lung cancer and the relative lung cancer mortality rates among asbestos insulation production employees according to time from onset of of employment.

Figure 2-3



The death rates for mesothelioma among insulation workmen according to age and age at onset of employment, and according to time since onset of employment.

Figure 2-4

Table 2-19

Deaths among 17,800 asbestos insulation workers
in the United States and Canada
January 1, 1967 - December 31, 1976
Number of men 17,800
Man-years of observation 166,853

Underlying cause of death	Expected*	Observed (BE)	Observed (DC)	Ratio o/e (BE)	Ratio o/e (DC)
Total deaths, all causes	1658.9	2271	2271	1.37	1.37
Total cancer, all sites	319.7	995	922	3.11	2.88
Cancer of lung	105.6	486	429	4.60	4.06
Pleural mesothelioma	†	63	25	-	-
Peritoneal mesothelioma	†	112	24	-	-
Mesothelioma, n.o.s.	†	0	55	-	-
Cancer of esophagus	7.1	18	18	2.53	2.53
Cancer of stomach	14.2	22	18	1.54	1.26
Cancer of colon-rectum	38.1	59	58	1.55	1.52
Cancer of larynx	4.7	11	9	2.34	1.91
Cancer of pharynx, buccal	10.1	21	16	2.08	1.59
Cancer of kidney	8.1	19	18	2.36	2.23
All other cancer	131.8	184	252	1.40	1.91
Noninfectious pulmonary diseases, total	59.0	212	188	3.59	3.19
Asbestosis	†	168	78	-	-
All other causes	1280.2	1064	1161	0.83	0.91

From Selikoff et al. (1979)

* Expected deaths are based upon white male age-specific U.S. death rates of the U.S. National Center for Health Studies, 1967-1976.

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

(BE) Best evidence. Number of deaths categorized after review of best available information (autopsy, surgical, clinical).

(DC) Number of deaths as recorded from death certificate information only.