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Roentgenographic Evidence of Asbestos Exposure in a Select Population of Railroad Workers

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A volunteer population of 266 current and former railroad workers was examined with posteroanterior and oblique chest roentgenograms, and a comprehensive occupational smoking history. Seventy-five percent of participants were over the age of 60, and 80% had fewer than 10 years of railroad-related asbestos exposure. Roentgenographic evidence of asbestosis was found in only six workers (2%), whereas 20% had one or more pleural changes. Radiological abnormalities were related to latency period, age, and occupation, but not to smoking habit. While selection factors qualify the results of this study, the findings support the exposure and suggest a past and future history of asbestos mortality and morbidity among steam era railway workers.

Key words: asbestos exposure, asbestosis, pleural disease, railway workers

INTRODUCTION

The processing and handling of asbestos or asbestos-containing products has resulted in occupational exposure to several million American workers. Exposed worker populations have included construction, insulation, textile, and friction product workers. The overhaul and construction of ships have also exposed many workers to asbestos, particularly during the period of heightened shipyard activity in the 1940s [U.S. Department of Labor, 1979]. Radiological surveys among workers in these industries have demonstrated a high prevalence rate of asbestos-induced pleural abnormalities and diffuse interstitial pulmonary fibrosis (asbestosis) [Selikoff et al, 1965; 1979; Rossiter et al, 1972; Weill et al, 1973; Berry et al, 1979].

Several recent reports of asbestos-associated diseases among railroad workers have suggested a significant asbestos exposure in railroad shops during the construction and repair of steam-powered locomotives and railway vehicles [Webster et al,

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1977; Mostert and Meintjes, 1979; Cochrane and Webster, 1981]. In the United States, these activities occurred prior to the early 1950s and employed close to one-quarter of a million workers per year (Fig. 1). Asbestos esposure during this period resulted from the application and periodic removal of 85% magnesia blocks (85% magnesium, 15% asbestos) used as lagging for steam locomotive boilers and fire-boxes. Numerous other asbestos-containing products were also employed to insulate pipes and passenger cars [Johns-Manville, 1923]. The need for a variety of skilled craftsmen in these shops suggests an exposure to asbestos in a wide cross section of the different occupations (see Fig. 1).

A recent hazard evaluation by the National Institute for Occupational Safety and Health (NIOSH) identified four cases of diffuse malignant pleural mesothelioma in former workers of a railway shop facility in Pennsylvania. Coupled with the absence of published data on asbestos-related disease in American railroad workers, NIOSH was prompted to conduct a survey of steam era shop workers in this Pennsylvania community.

METHODS

The work site under study employed approximately 4000 workers per year in the two decades before 1950. From 50 to 60% of this population were craftsmen and laborers with potential exposure to asbestos in the railroad shop environment. From this group, workers with a minimum of 2 years of tenure at the facility prior to 1950, and currently residing in the general metropolitan area, were sought for inclusion in the program. For purposes of identifying these individuals, they were divided into two categories based on their employment status as of the bankruptcy of the rail line

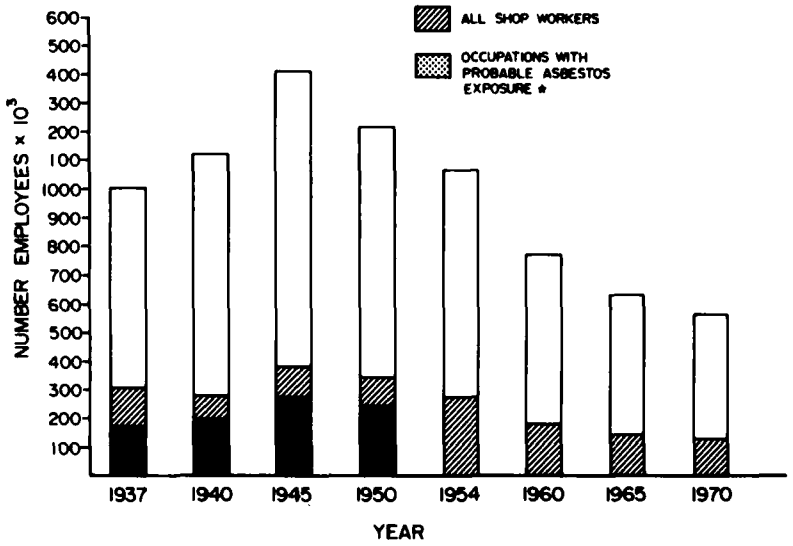

Fig. 1. Employment statistics of major U.S. railways showing total employment, all shop workers, and the subpopulation of the shop labor force likely to have had asbestos exposure. (*) Refers to boilermakers, machinists, carmen, skilled helpers, helper's apprentices, apprentices, classified laborers. Source: Statistics of Railways in U.S., 1937–1950. Transportation Statistics of U.S., 1954–1970.

in 1976. Persons employed after 1976 who met study entry criteria were identified by management from current personnel records. Workers inactivated prior to 1976 had no personnel records with the current operators who acquired the bankrupt railroad in April 1976. Volunteers from this group were recruited from a local retired railway employees association, as well as through community media resources.

The testing program included administration by trained interviewers of a questionnaire detailing each previous occupation and smoking history. Chest radiography was also performed using standard 14 in. × 17 in. posteroanterior (PA) roentgenograms and right and left 45° obliques. Films were submitted to three certified pneumoconiosis ("B") readers for independent, blind interpretation. Each participant's PA and oblique chest films were read as a composite employing the 1980 ILO Classification of Radiographs of the Pneumoconioses [International Labour Office, 1980]. Pleural and parenchymal abnormalities were considered present if noted by at least two readers. Pleural abnormalities consistent with asbestos exposure were defined as pleural thickening (localized or diffuse) and/or pleural calcification in any thoracic location except the lung apices or costophrenic angles.

To assess the relation of age and years from onset of railroad work to roentgenographic abnormalities, logistic regression modeling employing general least squares and maximum likelihood methods were employed [Cox, 1970].

RESULTS

Two hundred and sixty-six volunteers meeting entry criteria were examined. The participation rate among active workers with pre-1950 tenure was 0.65 (39 of 60). Data provided by management showed no difference between volunteers from this group and nonparticipants in regards to age, tenure before 1950, years since onset of railroad work, and distribution of occupational groups. The majority of workers tested (N=227), however, were media recruits, and the size and composition of the population from which they volunteered are unknown.

The distributions of age and pre-1950 railroad tenure of those examined are shown in Table I. Most participants were between 60 and 69 years of age and had been employed in an asbestos environment (pre-1950 shop work) for less than 10 years. All participants were 30 or more years from the onset of railroad work or first exposure to asbestos. Of 266 participants, 43% were 30–39 years from initial exposure and 57% were 40 or more years since first exposure (Table II).

Radiological abnormalities associated with asbestos are shown in Table III for the study group. Pleural abnormalities were the most common finding and were observed in 20% of the workers examined. Among workers with pleural changes,

TABLE I. Distribution of Age and Pre-1950 Tenure for 266 Railroad Workers

	Pre-1950 railroad tenure (yrs)			
Age (yrs)	2–10	11–20	20+	Total
50–59	78	0	0	78 (29%)
60–69	102	8	0	110 (41%)
70–79	28	12	26	66 (25%)
80+	2	1	9	12 (5%)
Total	210 (79%)	21 (8%)	35 (13%)	266 (100%)

TABLE II. Distribution of Age and Years Since Onset of Railroad Work

	Years since onset of railroad work			
Age (yrs)	30–39	40–49	50+	Total
50–59	70	8	0	78 (29%)
60–69	34	72	4	110 (41%)
70–79	9	17	40	66 (25%)
80+	1	2	9	12 (5%)
Total	114 (43%)	99 (37%)	53 (20%)	266 (100%)

TABLE III. Distribution of Small Opacities Among Participants by Status of Pleura

	Pleura		
Small opacity profusion[a]	Normal	Abnormal	Total
0	209	49	258
1	3	3	6
2	2	0	2
3	0	0	0
Total	214	52	266

[a]The 1980 International Labour Office "Classification of Radiographs of the Pneumoconioses." [1980].

TABLE IV. Classification of Radiographic Abnormalities

Abnormality	Number	Study population (%)
Pleural thick. only[a]	2	1
Pleural plaque only	16	6
Pleural Ca^{2+} only	4	2
Multiple pleural change	27	10
Total pleural abn. only	49	18
Rounded opacity only	2	1
Irreg. opacity only	3	1
Irreg. op. + pleural abn.	3	1
Total abn. X rays	57	21

[a]Includes only diffuse pleural thickening.

pleural thickening with calcification was more common than diffuse or localized thickening alone (Table IV). Localized pleural thickening alone (plaques) was present in 31% of workers with abnormal pleurae. Roentgenographic evidence of pneumoconiosis was found in eight persons (3%). Irregular small opacities predominated in six of eight individuals, whereas rounded opacities alone were observed in two individuals. The parenchymal abnormalities were generally unequivocal with only two workers having profusion category 1/0. Of the six workers with pneumoconiosis characterized by irregular opacities (asbestosis), associated pleural abnormalities were present in three. No large opacities were observed.

Roentgenographic abnormalities were examined by occupation, years from first exposure, age, smoking, and other dust exposures. A striking clustering of abnormalities was observed in the study group by pre-1950 occupation (Table V). Among the various occupational groups, boilermakers and machinists contained the highest proportion of affected individuals, 33 and 30%, respectively, for pleural abnormalities. Interestingly, included in the miscellaneous category was a small group (N=7, crane operators) who accounted for five of the seven chest roentgenograms with pleural abnormalities in this cell.

The proportion of individuals with abnormal films appeared related to age and years from onset of railroad employment (or first exposure) (Table VI). The longer the interval from first employment or the older the age group, the higher the prevalence rate of pleural abnormalities. To assess the association of these two variables with pleural abnormalities, logistic regression analysis was performed on the data in Table VI. This statistical modeling procedure can be applied to estimate

TABLE V. Roentgenographic Abnormalities Among 266 Railroad Shop Workers by Occupation*

Occupation	Number	Small opacities[a] only	Pleural abnormality[b] ± small opacities
Boilermakers	27	1 (4%)	9 (33%)
Machinists	92	2 (2%)	28 (30%)
Carmen	30	1 (3%)	1 (3%)
Sheetmetal workers	24	0 (0%)	2 (8%)
Laborers	24	1 (4%)	2 (8%)
Electricians	23	0 (0%)	3 (13%)
All other occupations	46	0 (0%)	7 (15%)
Totals	266	5 (2%)	52 (20%)

*Principal railroad shop occupation prior to 1950.
[a]Small opacity profusion 1/0 or greater [International Labour Office, 1980] by at least two of three "B" readers.
[b]Pleural thickening and/or calcification noted by at least two of three "B" readers.

TABLE VI. Workers With Pleural Abnormalities by Age and Years Since Onset of Railroad Work

	Years since onset of railroad work			
Age (yrs)	30–39	40–49	50+	Total
50–59	9	0	0	9 (12%)[a]
60–69	4	18	0	22 (20%)[a]
70–79	3	3	12	18 (27%)[a]
80+	0	0	3	3 (25%)[a]
Total	16 (14%)[a]	21 (21%)[a]	15 (28%)[a]	52 (20%)[a]

	DF	Estimate	Chi square	Prob
Intercept[b]	1	−4.21	11.61	0.007
Age	1	+0.03	1.12	0.29
Years from onset	1	+0.02	0.71	0.40

[a]Percentage of *all* participants in each row/column.
[b]Logistic regression (maximum likelihood analysis).

TABLE VII. Roentgenographic Abnormalities in Relation to Cigarette Smoking

Smoking status	Number	Roentgenographic abnormality		
		Small opacity only	Pleural	
			(Observed)	(Adjusted)[a]
Smoker	58	1	7 (12%)	10 (17%)
Exsmoker	116	1	26 (22%)	21 (18%)
Never smoker	92	3	19 (21%)	18 (20%)

[a]Prevalence adjusted for age and years from onset of employment using logistic regression data (see Table VI).

TABLE VIII. Exposure to Dust in Other Than Railroad Shop Work

Other dust exposure	Number workers	Average years worked	Abnormal X rays
Coal	8	5	2
Silica	25	5	4
Cotton	3	3	0
Cement	2	9	0
Total	38		6

the effect of risk factors (eg, age, years from onset) on a dichotomous outcome, such as the presence or absence of radiographic abnormalities. The analysis yields an estimate of the risk factor's effect (eg, age) and computes the probability of the effect being no different from zero. In this study neither the estimate of the age coefficient nor the estimate of the years from onset of employment coefficient was statistically significant, but the trend of the coefficients was in the direction expected based on data from other investigations [Rossiter et al, 1972; Selikoff et al, 1979].

The occurrence of radiographic abnormalities by history of smoking is illustrated in Table VII. Of 266 participants, 22% were current smokers, 44% exsmokers, and 34% never smokers. Adjusting for differences between smoking categories for age and years since onset of employment revealed no difference in the prevalence rate of radiological findings among the various smoking categories.

Careful occupational inventories showed that 38 individuals had had exposure to other noxious dusts, largely coal and silica dusts (Table VIII). Roentgenographic abnormalities were present in 6 of these workers, and in each instance the specific abnormality noted was pleural. While pleural thickening is not an uncommon pathologic observation in subpleural lesions of coal workers' pneumoconiosis and silicosis [Parkes, 1982], roentgenographic pleural change in these diseases is uncommon [Morgan and Lapp, 1976; Ziskind et al, 1977].

DISCUSSION

The existence of an asbestos hazard in railway construction and maintenance facilities during the steam locomotive period was recognized by early observers of asbestos-exposed groups [Wagner et al, 1960]. Reports of asbestos-associated dis-

eases, which have included railroad workers, have generally focused on the occurrence of diffuse malignant pleural mesothelioma. Wagner and co-workers' landmark study [Wagner et al, 1960] linking asbestos exposure to malignant mesothelioma in North Western Cape Province contained two workers with railroad shop asbestos exposure. Additional series of malignant mesothelioma from numerous countries have contained railroad workers and support a generic exposure to asbestos in the steam railway industry [Lieben and Pistawka, 1967; Rubino et al, 1972; Greenberg and Davies, 1974; Nurminen 1975; Mostert and Meintjes, 1979].

The occurrence of nonmalignant asbestos pulmonary diseases among steam railway workers has not been adequately examined. Case studies of asbestosis in this industry have been reported from Rhodesia [Mostert and Meintjes, 1979] and South Africa [Webster et al, 1977] where insulation products for vehicles were predominantly crocidolite asbestos. No published data exist for pleural disease in workers of the industry.

The current survey includes a population of railway workers that is not representative of the work force at the facility prior to 1950. Participants are survivors of a worker population whose asbestos exposure ceased 31 years ago. It is expected, therefore, that these individuals are the fittest of the group and the least likely to exhibit the ill health effects of this exposure. Additional selective factors operative in this volunteer population include ambulatory health status, current residency in the community, membership in the retired railroaders association, and media recruitment of former workers separated before 1976. The effects of these nonrandom influences on study results are less clear than the survivor bias but further serve to limit the quantitative aspects of the findings. As previously noted, this survey also included 45° oblique chest roentgenograms. The enhanced sensitivity of PA and oblique chest films compared to the PA view alone cautions further against comparison of the findings to other occupational groups [Reger et al, 1982; Baker and Greene, 1982].

The roentgenographic findings in this select volunteer group support the survivor nature of the population examined. The low prevalence rate of penumoconiosis (3%) found may be explained in part by the decreased probability of survival in workers with pneumoconiosis. Increased mortality from asbestosis has been demonstrated in exposed workers [Selikoff et al, 1979; McDonald et al, 1980], and it is unlikely, therefore, that many affected railway workers would have survived to be examined more than 30 years after the exposure terminated. In contrast, pleural abnormalities were common in the study. This was not an unexpected finding given the high frequency of pleural disease in exposed worker populations, and the association of pleural changes, low level exposure, long latency period, and age [Lilis et al, 1979; Rossiter et al, 1972; Selikoff et al, 1979; Irwig et al, 1979]. In addition, enhanced morbidity or mortality from pleural thickening or calcification alone has not been demonstrated in asbestos-exposed populations where adequate adjustments have been made for dose and latency [Weill et al, 1973; Edge, 1979; Sheers, 1979; Jones et al, 1980].

The distribution of radiological abnormalities observed by dose (pre-1950 tenure), occupation, smoking, age, and years since onset of railroad employment are of some interest. The absence of environmental exposure data limited dose estimation to total years employment in shops during the era of steam-powered railways (pre-1950 tenure). Specific shop occupation or craft is seen to be an important factor in the development of pleural disease (Table VI) and by inference in exposure to asbestos.

The open nature of railroad shop facilities and the location of boilermakers and machinists in areas where asbestos was employed support the clustering of roentgenographic findings in these occupations. This observation may explain the absence of enhanced mortality from asbestos in a recently reported population of Japanese railway workers where consideration of occupation was absent [Hosoda et al, 1980].

In contrast to the findings of Weiss and associates [Weiss, 1971; Weiss et al, 1981], roentgenographic abnormalities were not observed to vary by smoking class. This has also been noted by Selikoff and co-workers [1980] and Rossiter and Harries [1979]. As in other investigations [Rossiter et al, 1972; Selikoff et al, 1979], both age and years from onset of first exposure appear to be important in the development of radiographic abnormalities. The lack of statistical signficance of coefficient estimates for these variables in this study may reflect the relatively low number of abnormal roentgenograms for logistic regression analysis.

This report serves to document some health effects from asbestos exposure in a volunteer group of railway workers. While selection factors limit the interpretation of the data, the occurrence of asbestos-related radiological findings suggests that this occupational group may be at risk for other adverse health effects from asbestos. The magnitude of the workforce employed at similar facilities during the steam epoch (Fig. 1) would suggest yet another asbestos legacy of disease [Selikoff et al, 1980]. The need for better assessment of the health experience of workers in this industry seems appropriate. The National Institute for Occupational Safety and Health is currently engaged in one such study to evaluate the mortality experience of selected occupations during this period.

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