OCCUPATIONAL ASBESTOSIS AND ASBESTOS RELATED DISEASES AMONG WORKERS EXPOSED TO ASBESTOS, 1987, THAILAND

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BACKGROUND

Occupational exposure to asbestos minerals constitutes a major health hazard in most industrialized nations of the world.[1]

Early case reports stimulated concern and in 1928 the detailed epidemiologic study of asbestos workers was undertaken by the Ministry of Labour in Great Britain. This was a cross-sectional chest X-ray study of 363 workers engaged in production of asbestos textiles. Of this group, 95 (26.2%) were found to have pulmonary fibrosis and the prevalance of fibrosis with 20 or more years employment was over 80%.[2]

Asbestosis is the name of the pneumoconiosis produced by the inhalation of asbestos fibers. It is characterized by diffuse interstitial fibrosis of lung parenchyma, often accompanied by thickening of the visceral pleura. Clinical findings include dyspnea on exertion, non productive cough, rales at the lung bases, bronchi, and in advanced cases, finger clubbing. Lung function measurements usually demonstrate a restrictive impairnent with reduced diffusing capacity.

The radiographic findings of asbestosis and asbestos related pleural plaques and thickening are best described through systematic application of the ILO-1980 Classification for interpretation of the pneumoconioses.[3] The small irregular opacities of asbestosis are most commonly distributed in the mid and lower lung zones.

Each year, Thailand imports about five million metric tons of asbestos to be used in friction and fire resistant materials. Industries include brake lining, clutch facing asbestos ceiling tiles, asbestos floor tiles, asbestos cement pipe and car undercoating.

These products are widely used in Thailand, but their hazards are not well-known here. They are exported to bring in money every year, but the employees do not know how hazardous asbestos is. More and more workers have been exposed to this potential health hazard while manufacturing asbestos products. It was claimed that there were no cases of asbestosis in Thai workers. The health status of exposed workers remains undescribed.

To find out whether there were asbestosis and asbestos related diseases among Thai workers, and to prepare the baseline data for the surveillance of asbestos related disease among the group of workers exposed to asbestos, thus we carried out a study concerned with this problem. The objectives of this study are, to study the prevalence of asbestos related diseases, to determine epidemiological distribution of asbestos related diseases, to survey knowledge, attitude and practice of workers in prevention of asbestos related diseases, to identify risk factors associated with asbestos related diseases, and to provide the knowledge in appropiate preventive and control measures of asbestos related diseases for all workers exposed to asbestos and all industries using asbestos.

METHODS

We conducted a descriptive epidemiological study, a survey of knowledge,attitude and practice in prevention of asbestos related diseases and a case-control study.

The descriptive study was done by surveying all 24 factories registered by ministry of industry that use asbestos in a production process. There are six provinces where this type of manufacturing is located. A11 are included in this study. All workers in these plants constitute the study group.

The workers were interviewed using questionaires that asked information regarding the examination with their work history and history of illness, knowledge and attitude prevention of asbestos related diseases. Chest radiograph, and lung function tests were carried out. The case definition was a worker exposed to asbestos for more than six months with chest radiograph change falling into a possible case and a definite case. A possible case of asbestos related disease had to have chest radiograph changes in parenchymal profusion of 1/0 together with at least one of the other abnormalities consistent with pneumoconiosis classified by international classification of puenmoconiosis-ILO-1980.[3] A definite case had to have chest radiograph changes in parenchymal abnormality profusion at 1/1 and above. The chest radiographs were read by a radiologist and an occupational health physician.

RESULTS

We surveyed twenty-four factories and performed 1,013 interviews, physical examinations, especially the respiratory system and lung function tests to workers. Six hundred and sixty chest posteroanterior radiographs were carried out.

There were thirty four cases that met our case definition. Thirty one cases were possible and three were definite cases

of asbestos related diseases, giving the prevalence rate of 5.1% among the whole group. All cases were male. The sex specific male prevalence rate was seven percent. Half of the cases were smokers. The mean age of the cases was 40 years old (range=21–53). Mean duration of exposure was 8.5 years (range=1–22).

Forty one percent of cases had symptoms including dyspnea, chest pain, chest tightness and weight loss. There were 50% of cases that had abnormal signs such as, diminished chest expansion and clubbing fingers. Mean forced expiratory volume in one second by forced vital capacity was 84%, and forced vital capacity by predicted FVC of a normal person at the same age, sex and height was 98%. All components of mean pulmonary function seem to be within normal limits. Forty four percent of cases had abnormal pulmonary function by the prediction equation of Crapro and coworker.[4] The predicted values were corrected with 0.85 for non caucasian people. Most of them (73%) were restrictive ventilatory defects. The chest expansion was 3.9 cm in average.

The three definite cases had chest radiographs of s and t in shapes and sizes with the small opacity parenchymal profusion of 1/2, 2/2 and 3/3. For the large opacity, there was one case of catagory 'B'. When it was considered in terms of other abnormalities, there were effusion(ef) of 5.8%, ill-defined diaphragm(id) of 5.8%, pleural thickening(pi) of 52.9%, pneumothorax(px) of 2.9%, calcification in small pneumoconiotic opacity (cn) of 11.76%, other significant abnormalities of volume loss at 5.8% and tuberculosis(tb) of 20.58%.

The highest prevalence rate of asbestos related disease was among workers in asbestos-cement pipe factory. The rate was 20%. The prevalence rate of asbestos related diseases among the workers in floor-tile was 5.3%, followed by 5.1% in ceiling tile, 4.7% in car undercoating and 2.1% in brake and clutch plants.

Asbestos-mixers had the highest prevalence rate of 23.5%, when it was analysed by job specific prevalence rate. There were 14.7% of prevalence rate among those who were tile machine operators, in addition with 14.7% in material deliverers, 11.8% in tile and pipe cutters, 5.9% in quality control personnel, 2.9% among the group of supervisers,and 2.9% in maintenance machanists.

The concentration of asbestos fibers collected by both area and personal samplings averaged at 2.5 fibers/ml and 5 fibers/ml, respectively. The maximum fiber concentration was 58.5 fibers/ml in one of brake-manufacturing plants. The recommended exposure limit by NIOSH of 0.1 fiber/ml was used to calculate the excess amount of fiber concentration in working atmosphere.[5] Such that maximum concentration was 585 times of REL. The asbestos used was mostly chrysotile, with some crocidolite and amosite.

In survey of knowledge, attitude, and practice, we found that only a third of the workers had been educated in preventive measures. Six percent said that they would continue their work, even if they were ill with an asbestos related condition. Ninety six percent of respondents wanted factories to provide protection. Almost all would use special masks if they were made available. Only thirteen percent of workers had annual medical examinations, and 1 % currently used masks approved by NIOSH. Twenty six percent of workers had ever received 16*17 inches films.

In the case-control study, cases and controls were not different in age, but significantly different in duration of exposure, vital capacity and forced vital capacity by predicted forced vital capacity ($p<0.05$ by student's t-test). Cases and controls were significantly different in proportions with restrictive lung defects. Cases and controls had similar smoking habits. Cases were significantly more likely to be asbestos mixers. The odds ratio was 21.3 with a 95% confidence interval limit that excluded zero.

DISCUSSIONS AND RECOMMENDATIONS

The study concluded that there were thirty four cases of asbestos related diseases attributable to work exposure. Prevalence was 5.1%. The workers most at risk were asbestos mixers and those who had long exposure to asbestos. Workers's knowledge, attitude and practice about the hazards of asbestos and prevention of asbestos related disease was very inadequate. The working conditions were also unsafe. When compared to the prevalence of asbestosis among railroad workers in the United state,[6] the prevalence in this study was three times higher. Morbidity and mortality analysis by Lacquet et al. (1979) of workers in a Belgian asbestos cement factory revealed a strong dose-response relationship for asbestosis, and pleural and parenchyma lung changes. Pleural thickening and adhesions began occurring in the lowest dose category (0-49 fibers/cc-year).[7] The concentrations in air of asbestos in this study were in the same range of that Belgium cement pipe in 1979 which could cause abnormalities in chest radiographs. The corresponding results led us to know for certain about the outcome of this study. This study did not include workers outside the plant that used asbestos even when they were part of the same workplace. These workers should be prospective to assess long term risk. Available epidemiologic data support a linear, no threshold dose-response relationship between asbestos exposure and the risk of lung cancer. And in additiona, no threshold has been convincingly demonstrated for non-malignant respiratory diseases associated with asbestos exposure. Thus, any asbestos exposure that carries with it some increased risk of asbestos exposure should be eliminated or reduced to the lowest level possible.

Appropriately designed and maintained engineering techniques are the control method of choice where asbestos substitutes cannot be used. Processing of asbestos in a wet state has been shown to be an effective control method in many asbestos processing industries, including the asbestos textile industry. The most commonly used control measure in asbestos processing plants is local exhaust ventilation whereby liberated dust is collected at the dust source and removed from the breathing zone of workers.

In this study, the control measures provided during and after the survey included reduction of asbestos dust in the workplace by the use of local hood ventilation and the establishment of better occupational health services. A better canteen was established to avoid having workers eat lunch on the piles of asbestos bags.

Periodic medical examinations were begun. Adequate and approved protective masks were providing along with training on how to use them effectively. Such measures should avoid the inadequate dust control measures now taken by workers.

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ACKNOWLEDGEMENTS: The authors would like to acknowledge Prof. Dr. Hjordia Foy of University of Washington, Seattle, USA, Dr. Nicholas Wright of CMDNJ, Robert Wood Johnson Medical School, Robert University, New Jersey, USA, Dr. Bruce G. Weniger of CDC, Atlanta, USA and Dr. Khumenit Limpakrnjurarat of Thailand.

RESPIRATORY MORBIDITY IN PLUMBERS AND PIPEFITTERS: THE RELATIONSHIP BETWEEN ASBESTOS AND SMOKING

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INTRODUCTION

Plumbers and pipefitters, along with other building trades workers, have been shown to be at risk for asbestos-related lung diseases including lung cancer,[1,2] mesothelioma,[3,4] and interstitial fibrosis.[5] In the present cross-sectional study, an Upstate New York chapter of a plumbers and pipefitters union was evaluated for evidence of asbestos exposure and disease. Our purpose was to better define the relationship among the clinical endpoints used to characterize asbestos exposure and non-malignant disease as well as the interactive effects of smoking.

METHODS

All active and retired members with pension eligibility received a mailed offer of free asbestos screening examinations. The voluntary evaluations, conducted over a four month period in 1986-1987, included an interview, physical examination, spirometry, and chest radiograph. Out of the total union membership of 975, 797 persons were eligible. Of these, 343 (43%) accepted the offer. Those who did not respond tended to be older, retired, and living out-of-state; hence the study group represented a younger, more active, and perhaps healthier subset.

Trained interviewers took a detailed occupational and medical history, with smoking and respiratory questions obtained from the Epidemiology Standardization Project.[6] The physical examination sought evidence of rales and clubbing. Dyspnea was graded according to the Medical Research Council criteria.[7] On spirometric examination, 3 maximum expiratory flow volume loops were obtained, using the Eagle Three Survey Spirometer (W.C. Collins). Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), flow at 75% of vital capacity (FEF_{75}), and late expiratory flow volume (FEF_{75-85}) were measured. Computations were based on the largest values for FVC and FEV_1. Maximum ventilatory volume (MVV) was also tested. Predicted values based on sex, age, and height for FVC, FEV_1, FEF_{75}, FEV_1/FVC, and MVV were computed using the regression equations of Crapo et al.[8] The Mt. Sinai algorithm as described by Miller[9] was used to define obstruction, restriction, and small airways abnormality.

Posteroanterior, lateral, and oblique chest radiographs (16" x 17") were taken at maximal inspiration and were interpreted by one "B" reader according to the ILO/UC Classification of Radiographs.[10] Pleural change consistent with asbestos exposure was defined as any pleural thickening, diffuse or circumscribed, bilateral or unilateral, excluding changes clearly due to factors not related to asbestos. Parenchymal change considered positive for possible asbestosis was defined as the presence of opacities of size s or t and profusion 1/0 or greater.

Analyses used the Statistical Analysis System (Cary, N.C.). Univariate tests evaluated the prevalence of pulmonary findings. Two-way analyses looked at age, duration of exposure, and other characteristics. Differences between groups were tested using frequency x^2 and t-tests.[11] Multivariate linear regression evaluated the predictive power of age, latency, and smoking in determining FVC and % predicted FVC.[12] Unconditional logistic regression models were used to control simultaneously for several independent variables that affected the probability of pleural or parenchymal change.[13] Two logistic regression models were developed, potentially including age, pack years, and years since first exposure as independent variables. The first model compared the characteristics of those subjects with only pleural change to those classified as normal. The second model compared the characteristics of those with parenchymal change (s,t > 1/0) to normals and to those with pleural change only.

RESULTS

Of the 343 participants, all were male, the mean age was 47, and mean years in the union was 22. 12.5% were retired. 38% were current smokers, and 39.5% were ex-smokers. Job experience was heterogenous, with numerous work sites, many contractors and conditions, and a variety of tasks. Virtually all workers reported a history of tasks that included asbestos exposure. The variation in work history precluded estimation of dose. Our analyses used years-since-first-exposure as a measure of latency.

Current smokers showed lower mean and percent predicted function for all measurements of pulmonary function, while ex-smokers (who on average were older than current smokers) were generally intermediate between smokers and non-smokers. (Table I) Ex-smokers showed the highest prevalence of obstruction, restriction, and small airways abnormality. (Table II) However, because more than 25% of these ex-smokers reported quitting less than five years prior to the screening, these data may reflect a subset who quit because of respiratory symptoms or diagnosed lung disease.

Table I
Mean Lung Function Value by Smoking Category

Smoking Status	Age	FVC (% Pred)	FEV_1 (% Pred)	FEF 75 (% Pred)	FEV_1/FVC (% Pred)
Never (n=72)	43.0	4.66 (94)	3.94 (98)	4.36 (107)	84.6 (104)
Former (n=139)	50.2	4.30 (90)	3.53 (92)	3.79 (99)	81.8 (102)
Current (n=121)	43.4	4.37 (89)	3.55 (89)	3.61 (89)	81.0 (100)

Table II
Diagnosis of Lung Impairment

	N	OBSTRUCTION (%)	RESTRICTION (%)	SMALL AIRWAYS ABNORMALITY(%)
Nonsmokers	72	1 (1.4)	6 (8.3)	7 (9.7)
Ex-smokers	139	4 (2.9)	28 (20.1)	49 (35.3)
Smokers	121	1 (.8)	23 (19.0)	33 (27.3)
TOTAL	332	6 (1.8)	57 (17.2)	109 (26.8)

In linear regression analyses, age, pack-years, years-since-first-exposure to asbestos, and parenchymal change (s,t > 1/0) were potentially included in a model to predict actual FVC. However, since most subjects had spent their working lives mainly in the trade, age and years-since-first-exposure were highly correlated (r=.89). Because it is difficult to interpret the independent effect of either factor when both are included in the model, and because age is a strong predictor of pulmonary function, age rather than latency was included in subsequent models. FVC showed a negative relationship with age ($p < .0001$), pack-years ($p < .0001$), and presence of parenchymal change ($p < .004$).

Nearly one-third of the study subjects showed either pleural and/or parenchymal change consistent with asbestos exposure. (Table III) 79 subjects (23%) had pleural change; 53 of these (67%) were bilateral. Two-thirds of the 42 subjects with parenchymal change had the lowest level of profu-

Table III
Characteristics of Those with Radiographic Abnormalities

Characteristic		Normal	Pleural Only	p	Parenchymal Only	p	
Age				<.001		<.001	a
	<40	116 (47)	5 (9)		2 (5)		
	41-60	119 (49)	36 (65)		24 (57)		
	>60	9 (4)	14 (26)		16 (38)		
Latency				<.001		<.001	a
	<15	82 (34)	3 (6)		5 (12)		
	16-25	89 (37)	12 (22)		3 (7)		
	26-35	51 (21)	17 (31)		14 (33)		
	>35	22 (9)	23 (42)		20 (48)		
Ever Smoker		181 (75)	48 (87)	.031	38 (91)	<.016	c
Dyspnea		50 (21)	14 (28)	.196	22 (55)	<.001	c
Rales		6 (3)	3 (5)	.218	12 (29)	<.001	b
Clubbing		4 (2)	4 (7)	.038	9 (22)	<.001	b
Restriction		25 (11)	11 (21)	.051	20 (49)	<.001	c

a t-test, comparing mean value (not shown)
b Fisher's exact test, comparing each abnormal group to normal group
c x^2 test, comparing each abnormal group to normal group

sion considered positive for possible asbestosis (1/0), while the rest had profusion from 1/1 to 2/1. Twenty-four men (7%) had both pleural and parenchymal change.

The likelihood of having either pleural or parenchymal change increased with the number of years since first exposure. (Figure 1) Among those with latency >25 years, the prevalence of pleural change was nearly 50%, while 66% had either pleural or parenchymal change. Those with parenchymal change were more likely to be older, current smokers, and to have other pulmonary findings (dyspnea, rales or clubbing, restriction, and small airways abnormality) than those with normal radiographs or with pleural change only.

After controlling for age using logistic regression modeling, latency did not remain a significant predictor of either parenchymal or pleural change. Smoking measured as a categorical variable (current, never, or former smoking) was significantly ($p=.04$) related to the presence of parenchymal change after controlling for age. However, if pack-years was included in the model with age instead of smoking category, the term did not attain statistical significance ($p=.14$). After controlling for age, neither pack-years nor smoking category predicted pleural change.

Dyspnea and pleural change were the most prevalent endpoints overall. (Table IV) Because, in the absence of pathological evidence, parenchymal change is considered the most important diagnostic criterion for asbestosis,[14] we sought its best predictors. In this study, rales and clubbing had the highest predictive value but were the least sensitive measures. Dyspnea and/or restriction were most sensitive, but even these parameters identified only about half of those with radiographic evidence of significant fibrosis.

DISCUSSION

The high prevalence of possible asbestosis and other respiratory morbidity potentially associated with asbestos exposure in this study is consistent with other cross-sectional studies of plumbers and pipefitters. In our group (mean age 47), 12% showed parenchymal change consistent with possible asbestosis, and an additional 16% showed only pleural changes. Sprince at al.[5] described parenchymal opacities (> 1/0) in 8% of a similarly aged group of plumbers and pipefitters where 17% showed pleural change. In a slightly younger group (mean age 42), Schwartz et al.[15] found 29.5% had bilateral pleural change and/or parenchymal opacities.

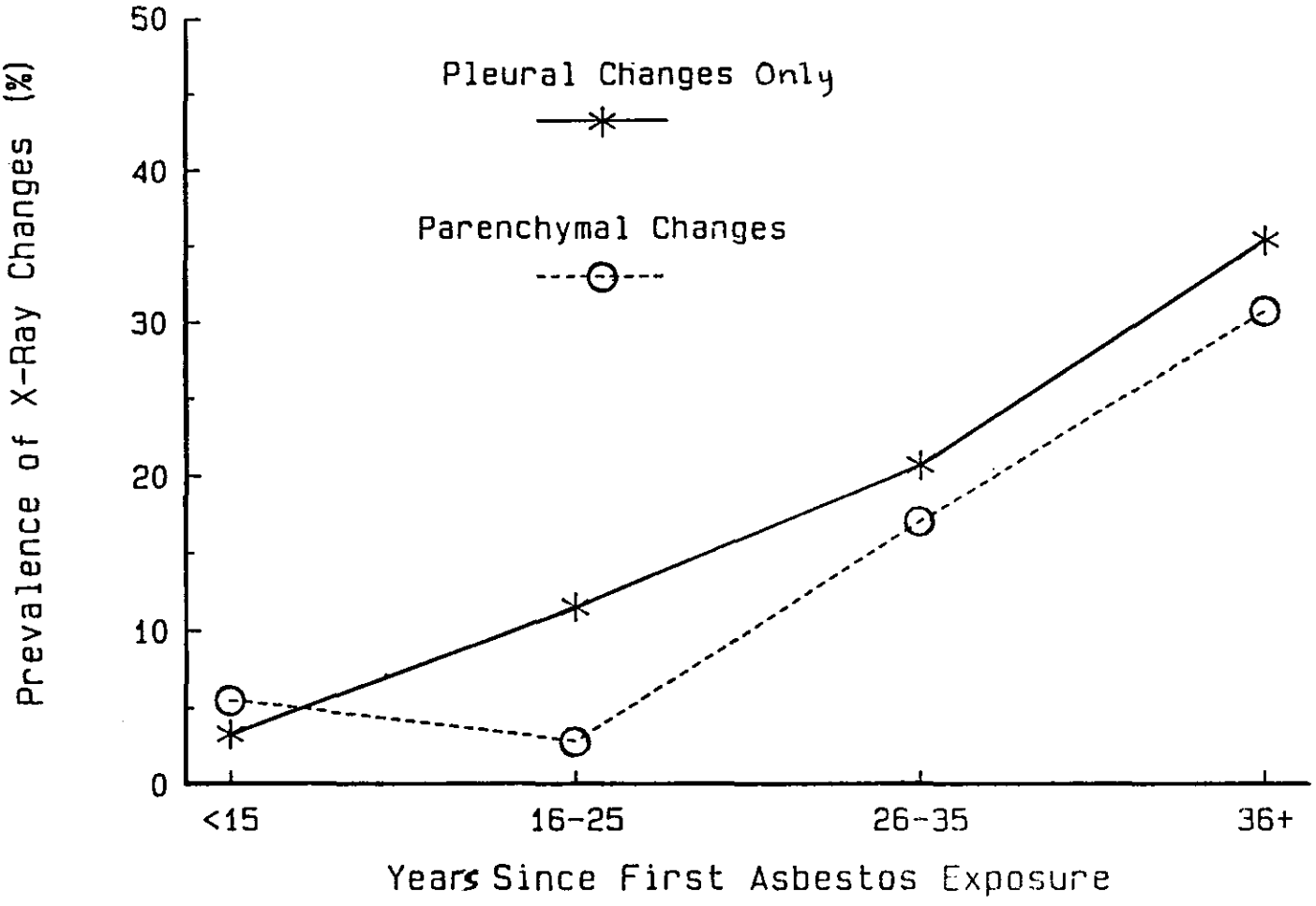

Figure 1. Prevalence of X-ray changes by years since first exposure.

Assessment of past exposure in the building trades is difficult. Given any history of exposure, age is the strongest predictor of asbestos-associated morbidity. But there are at least three other factors, systematically associated with age, which obscure the effect of age: (a) the lessening intensity of asbestos exposure over time, suggesting higher doses in older workers; (b) the secular trend in smoking habits; and (c) the collinearity with age of years-since-first-exposure.

Weiss[16] has argued that smoking is an independent cause of pulmonary fibrosis. Kilburn et al.[17] modified this view, suggesting that, while smoking alone does not produce fibrosis, it seems to have an additive effect to exposure to asbestos. Univariate analysis in the present study showed a relationship between smoking and the presence of parenchymal opacities. However, after controlling for age using logistic regression analysis, smoking was significantly associated with parenchymal change only when considered categorically (never, former, current), and not when pack-years was used as the smoking measure. This discrepancy may indicate a weak or non-existent association, the presence of an unknown confounder, or misclassification. Or it might illustrate the problem of using pack-years as a meausre of dose.

Each of the parameters studied here (history, physical examination, spirometry, and chest radiograph) has been used in the absence of pathological evidence to infer the presence of possible asbestosis. Evaluated alone, each parameter would identify a slightly different subset of subjects as potentially diseased. Even those persons with radiographic evidence of fibrosis did not consistently show other deficits; only 55% reported dyspnea, and only 56% had spirometric evidence of restriction. Conversely, the study identified a group of workers who had one or more of the criteria for the diagnosis of asbestosis (restriction, clubbing, rales, dyspnea) but who lacked radiographic evidence. These diagnostic problems were discussed by Murphy et al. a decade ago[18] but our study demonstrates that they are still incompletely resolved. Our examination of the relationship between smoking and interstitial change in an asbestos-exposed population illustrates an additional problem in classification: the differing conclusions resulting from the

Table IV
Clinical Endpoints

	Parenchymal Change	Pleural Change	Restriction	Clubbing	Rales	Dyspnea	N
Parenchymal Change		24(57)	20(49)	9(22)	12(29)	22(55)	42
Pleural Change	24(30)		24(30)	10(12)	10(13)	25(34)	79
Restriction	20(36)	24(43)		6(11)	11(19)	32(56)	57
Clubbing	9(53)	10(59)	6(35)		5(29)	11(65)	17
Rales	12(57)	10(48)	11(55)	5(24)		11(52)	21
Dyspnea	22(26)	25(29)	32(39)	11(13)	11(13)		26

use of smoking category or pack-years. Future studies of asbestos-exposed populations should carefully examine these issues.

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RADIOGRAPHIC ABNORMALITIES IN A LARGE GROUP OF INSULATORS WITH LONG TERM ASBESTOS EXPOSURE: EFFECTS OF DURATION FROM ONSET OF EXPOSURE AND SMOKING

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ABSTRACT

Chest radiographs and spirometry were evaluated in active and retired asbestos insulators selected to be ≥20 years since entry into the trade (DURONSET). Testing was performed in 19 cities in the U.S. and Canada during the years 1981–1983. Complete demographic, smoking, clinical, and radiologic data were obtained for 2790 workers. The total of 2790 insulators is the largest which has been reported: 548 (19.7%) were nonsmokers, 942 (33.9%) current smokers and 1300 (46.6%) past smokers.

Only 439 (15.7%) had no radiographic evidence of asbestos-related disease (normal); 1358 (48.7%) had both parenchymal and pleural fibrosis, 668 (23.9%) had pleural fibrosis only and 325 (11.6%) parenchymal fibrosis alone. The prevalence of radiographic abnormalities for parenchymal changes increased from 38.6% (DURONSET <30 years) to 70% (≥40 years). For pleural changes the respective prevalences were 55% and 82%.

Nonsmokers were more likely to have normal films than current and ex-smokers (19.2% vs 15.0%) and less likely to have parenchymal fibrosis (36.3% vs 51.3%). Current smokers were least likely to have normal films (14.4%) and most likely to have parenchymal fibrosis (69.7%); ex-smokers were intermediate but closer to current smokers. These findings were not explainable by the minor differences in age or DURONSET.

Dyspnea (MRC grade 3 and higher) was significantly more prevalent when pleural fibrosis was associated with interstitial pulmonary fibrosis (at all profusion levels of small opacities).

a. parenchymal abnormalities associated with pleural abnormalities
b. total pleural abnormalities and
c. total parenchymal abnormalities.

Small Irregular Opacities indicating the Presence of Interstitial Pulmonary Fibrosis were found with higher prevalence as duration from onset of exposure increased. Within each category of duration from onset of exposure (DURONSET) less than 29 years, 30 to 39 years, 40 years and over, prevalence of interstitial pulmonary fibrosis was consistently higher in persons with a positive smoking history than in workers who had never smoked (Figure 1 and Table III).

Profusion category increased with duration from onset of asbestos exposure; within each DURONSET category smokers had higher prevalence rates for more advanced interstitial fibrosis (Figure 2).

Thus, **cigarette smoking had a demonstrable effect on both prevalence of interstitial pulmonary fibrosis and on severity of interstitial pulmonary fibrosis.**

Pleural fibrosis (chest wall, in profile and/or face on) was a frequent finding. Prevalence rates increased with DURONSET; in contrast with parenchymal abnormalities the prevalence of pleural thickening did not differ significantly in those with a positive smoking history when compared to those who had never smoked (Figure 3).

Similar relationships were found for diaphragmatic pleural plaques; their prevalence increased with DURONSET, while no effect of smoking status could be detected (Figure 4).

Table I

Chest X-ray Findings in Asbestos Insulation Workers with Long Term Exposure

	N	%
Normal chest x-ray	439	15.7
Parenchymal changes only	325	11.6
Pleural changes only	668	23.9
Parenchymal and pleural changes	1358	48.7
Total parenchymal abnormalities	1683	60.3
Total pleural changes	2026	72.6

Table II

Radiologic Changes and Years from Onset of Asbestos Exposure

	Time from onset of asbestos exposure(years)					
	Less than 29		30-39		40 and over	
	N=368		N=1712		N=710	
Radiologic abnormalities	N	%	N	%	N	%
Parenchymal only	44	12.0	222	13.0	59	8.3
Pleural only	106	28.8	413	24.1	149	21.0
Parenchymal and pleura	98	26.6	824	48.1	436	61.4
Total pleural abnormalities	204	55.4	1237	72.3	585	82.4
Total parenchymal abnormalities	142	38.6	1046	61.1	495	69.7
Normal chest x-ray	120	32.6	253	14.8	66	9.3

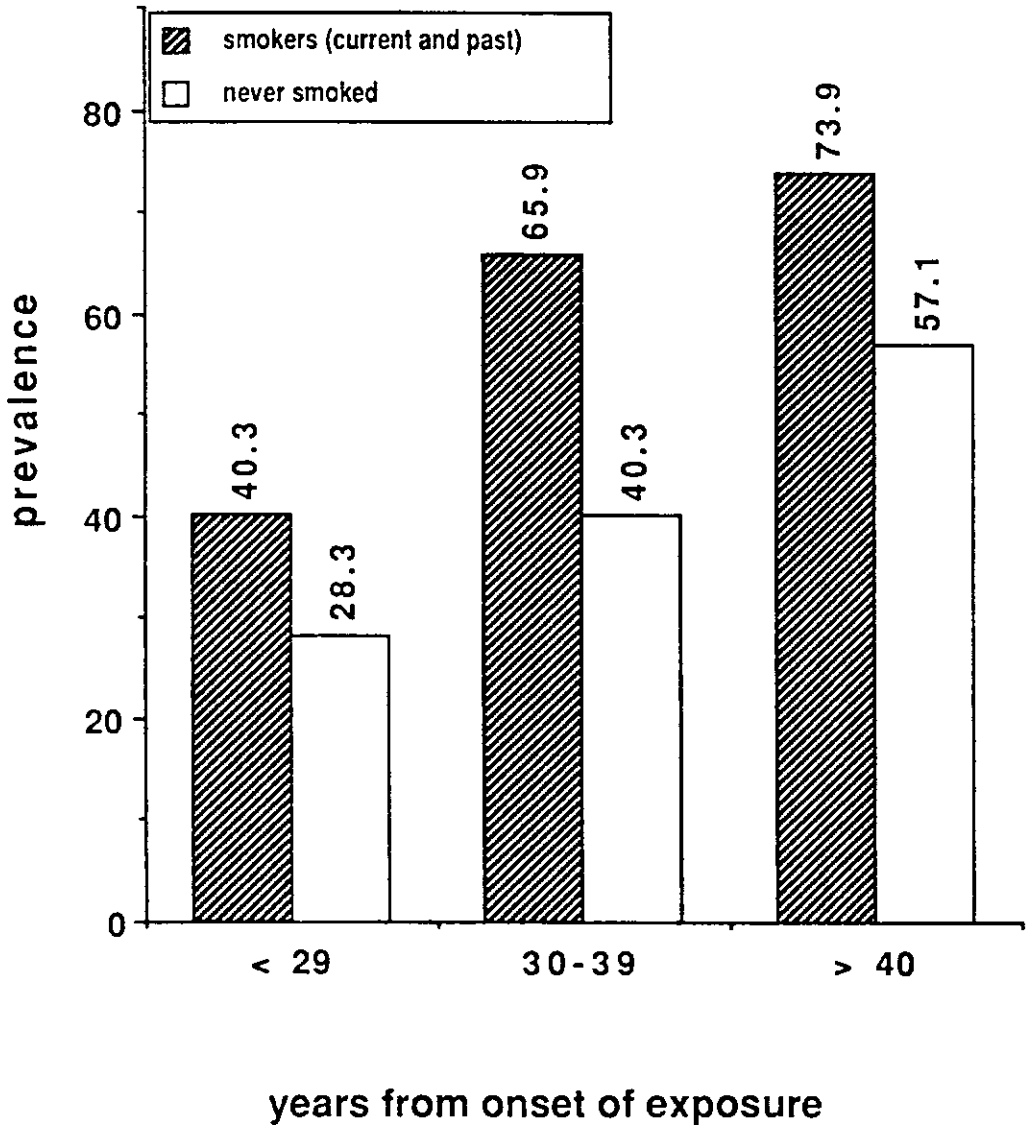

Figure 1. Interstitial pulmonary fibrosis (parenchymal small opacities) relationship with duration from onset of exposure and cigarette smoking.

Pleural calcifications showed an identical trend; increase of prevalence with DURONSET and no detectable effect of smoking status (Figure 5). Pleural calcifications extent grade 2 and grade 3 steadily increased with profusion of small opacities (Table IV).

The prevalence of pleural fibrosis was influenced by time from onset of asbestos exposure; smoking status did not seem to affect the development of pleural fibrosis.

The prevalence of total pleural abnormalities (pleural fibrosis, diaphragmatic plaques and pleural calcifications) increased with profusion of small opacities (Figure 6). Interestingly, more than half (60.3 percent) of those without radiologically detectable interstitial fibrosis (0/0–0/1) had pleural fibrosis.

Cigarette smokers were found to have more interstitial pulmonary fibrosis (as the only finding or associated with pleural fibrosis) than did nonsmokers; pleural fibrosis only was a considerably more frequent finding in nonsmokers than in smokers. Normal chest X-rays were also more frequent in non smokers (Figure 7 and Table V).

Regression techniques were used to assess the significance of the variables age, DURONSET, duration of exposure and smoking on the outcome parenchymal interstitial fibrosis (only and total i.e. associated with pleural fibrosis) and pleural fibrosis (only and total, i.e., associated with parenchymal fibrosis). The significant contribution of smoking to the finding of parenchymal abnormalities was demonstrated (Tables VI, VII). The variable DURONSET was very closely

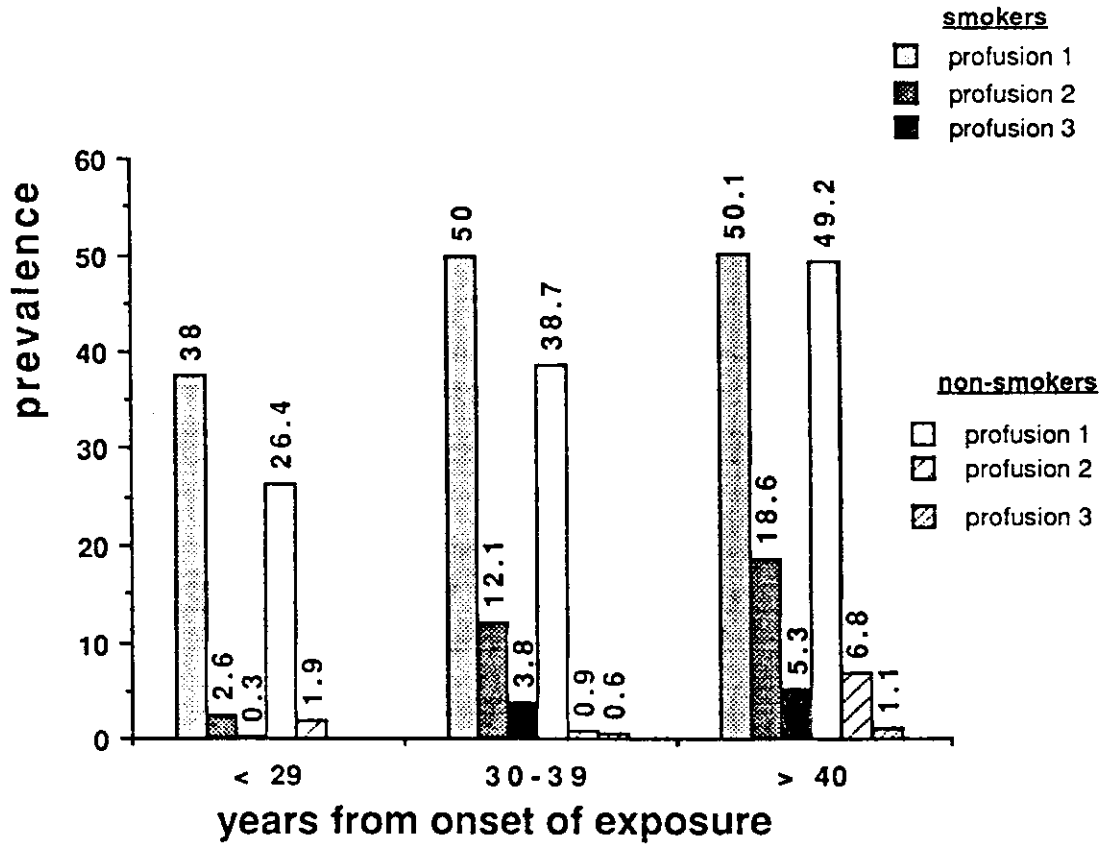

Figure 2. Parenchymal small opacities (profusion) relationship with duration from onset of exposure and cigarette smoking.

correlated with age ($r=0.79$, $p<0.0001$); when age was removed from the model, years since first exposure contributed significantly to parenchymal abnormalities.

Regression analysis demonstrated that, in contrast to parenchymal abnormalities, smoking made no contribution to pleural abnormalities. DURONSET was a significant factor even when age was in the model (Tables IX and X, XI and XII).

The presence and severity of the cardinal symptom of asbestosis, dyspnea on exertion, was assessed by questionnaire (MRC). Prevalence of dyspnea (grade 3 and over) was found to be higher in the subgroup with parenchymal interstitial fibrosis associated with pleural fibrosis than in that with parenchymal fibrosis only, at all three levels of profusion of small opacities (1/0–1/2; 2/1–2/3; 3/2–3/4). The difference in prevalence (Table XIII) was found to be statistically significant ($x2=5.09$, $p=0.024$).

Logistic regression analysis of dyspnea indicated, in addition to the significant contribution of DURONSET and years exposed, that the presence of pleural and parenchymal abnormalities was a significant explanatory variable, although parenchymal abnormalities only was not. The variable profusion of small opacities showed similar relationships, i.e., a highly significant contribution to dyspnea when associated with pleural abnormalities (Tables XIV and XV).

These results indicate that asbestos induced pleural fibrosis significantly contributes to dyspnea.

CONCLUSIONS

Pleural fibrosis is a very frequent effect of asbestos exposure. With lower levels of exposure than those of asbestos insulation workers the ratio of pleural fibrosis prevalence to interstitial fibrosis has been found to be higher.[4,5,6,7,8,9]

The results of this study indicate that pleural fibrosis contributes to dyspnea; this is in concordance with data reported by other investigators.[6,8,10,11,12,13,14] Thus, evidence has accumulated indicating that pleural fibrosis is an asbestos induced pathologic process, which after reaching a certain level/extent, adversely affects respiratory function, resulting in dyspnea.

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Table III

Interstitial Pulmonary Fibrosis (Profusion of Small Opacities) Relationship with Duration from Onset of Exposure and Smoking Status

Years from onset of exposure	Smokers		Never Smoked		
Less than 29 years					
Small opacities Profusion	N	%	N	%	p-value**
grade 1	118	93.0	14	93.3	n.s.
grade 2	8	6.3	1	6.6	n.s.
grade 3	1	0.8	0	_	n.s.
30-39 years					
	N	%	N	%	
grade 1	697	75.9	123	96.1	<0.0001
grade 2	168	18.3	3	2.3	<0.0001
grade 3	53	5.7	2	1.6	0.004
40 + years					
	N	%	N	%	
grade 1	267	67.8	87	86.1	<0.001
grade 2	99	25.1	12	11.9	<0.0001

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Table IV

Pleural Calcifications and Profusion of Small Opacities in Asbestos Insulation Workers with Long Term Exposure

Parenchymal radiologic abnormalities category	Total N	PLEURAL CALCIFICATIONS GRADE 1 N	%	2 N	%	3 N	%	Total N	%
0/0-0/1	1107	89	8.0	160	14.5	91	8.2	340	30.7
1/0-1/2	1306	146	11.2	235	18.0	216	16.5	597	45.7
2/1-2/3	291	37	12.7	61	21.0	69	23.7	167	57.4
3/2-3/4	86	8	9.3	22	25.6	21	24.4	51	59.3
TOTAL	2790	280	10.0	478	17.1	397	14.2	1155	41.4

Table V

Distribution Patterns of Radiographic Abnormalities by Smoking Category

Radiologic Abnormalities	Non smokers N=548		Current smokers N=942		Ex smokers N=1300	
	N	%	N	%	N	%
Parenchymal only	45	8.2	154	**16.3**	126	9.7
Pleura only	199	**36.3**	149	15.8	320	24.6
Parenchyma and Pleura	199	36.3	503	**53.4**	656	**50.5**
Any Parenchyma	244	44.5	657	69.7	782	60.2
Any Pleura	398	72.6	652	69.2	976	75.1
Normal	105	19.2	136	14.4	198	15.2
Age (mean ± SE)	58.7±.373		55.2±.244		58.7±.223	
Years from onset of exposure (mean ± SE)	36.4±.333		33.2±.217		36.0 ±.200	

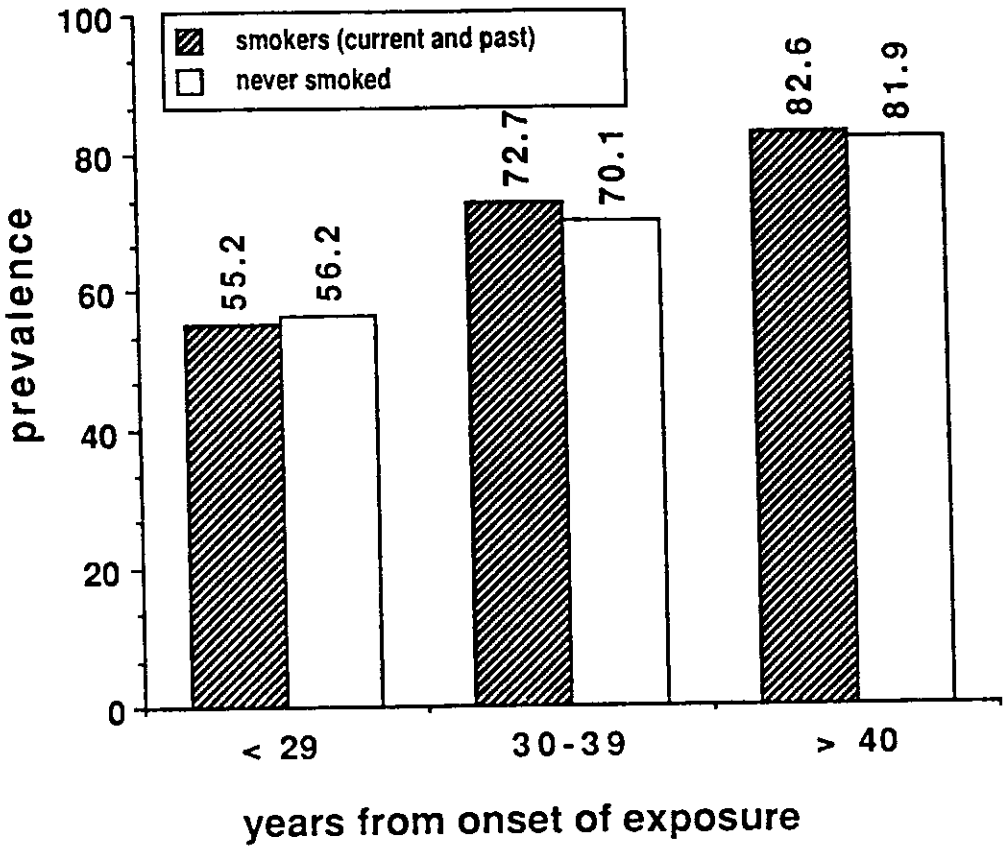

Figure 3. Pleural fibrosis relationship with duration from onset of exposure and cigarette smoking.

Table VI
Logistic Regression Analysis of Parenchymal Abnormalities (Only)

Explanatory Variable	Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept	-4.203 (.557)	57.02	.0001
Age	.054 (.015)	13.17	.0003
Years since first exposure	-.005 (.021)	.06	.8113
Years exposed	.022 (.014)	2.33	.1265
Packyear	.013 (.003)	22.21	**.0001**
MODEL EXCLUDING AGE			
Intercept	-2.80 (.383)	53.33	.0001
Years since first exposure	.047 (.015)	9.13	**.0025**
Years exposed	.017 (.014)	1.53	.2165
Packyear	.014 (.003)	25.23	**.0001**

Table VII
Logistic Regression Analysis of Parenchymal Abnormalities (Total)

Explanatory Variable	Regression Coefficient (±SE)	Chi-square	P-value
Intercept	-3.604 (.315)	130.85	.0001
Age	.0471 (.008)	33.10	.0001
Years since first exposure	.012 (.011)	1.19	.2748
Years exposed	.014 (.007)	4.20	.0404
Packyear	.015 (.002)	90.52	**.0001**
MODEL EXCLUDING AGE			
Intercept	-2.34 (.221)	111.94	.0001
Years since first exposure	.057 (.008)	53.25	**.0001**
Years exposed	.010 (.007)	1.92	.1659
Packyear	.015 (.002)	96.83	**.0001**

Table VIII

Logistic Regression Analysis of Parenchymal Abnormalities* (Profusion Categories)

Explanatory Variable		Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept(	prof0 vs. prof3)	6.656 (.624)	113.85	.0001
	(prof1 vs. prof3)	4.475 (.611)	53.59	.0001
	(prof2 vs. prof3)	.682 (.670)	1.03	.3096
Years since first exposure	(prof0 vs. prof3)	-.102 (.019)	30.22	**.0001**
	(prof1 vs. prof3)	-.053 (.018)	8.58	**.0034**
	(prof2 vs. prof3)	-.023 (.020)	1.25	.2627.
Years exposed	(prof0 vs. prof3)	.012 (.017)	.47	.4908
	(prof1 vs. prof3)	.020 (.017)	1.43	.2313
	(prof2 vs. prof3)	.041 (.019)	4.54	.0332
Packyear	(prof0 vs. prof3)	-.024 (.003)	47.34	**.0001**
	(prof1 vs. prof3)	-.011 (.003)	11.53	**.0007**
	(prof2 vs. prof3)	.00063 (.004)	.03	.8576

* Age excluded from the model

Table IX
Logistic Regression Analysis of Pleural Abnormalities (Only)

Explanatory Variable	Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept	-2.466 (.451)	29.86	.0001
Age	.028 (.013)	4.50	.0338
Years since first exposure	.041 (.017)	5.55	**.0185**
Years exposed	.001 (.011)	.02	.8911
Packyear	.002 (.003)	.39	.5320
MODEL EXCLUDING AGE			
Intercept	-1.784 (.310)	33.06	.0001
Years since first exposure	.068 (.012)	29.29	**.0001**
Years exposed	.00002 (.011)	0.00	.9982
Packyear	-.001 (.002)	.17	.6764

Table X
Logistic Regression Analysis of Pleural Abnormalities (Total)

Explanatory Variable	Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept	-2.392 (.327)	53.57	.0001
Age	.028 (.009)	10.51	.0001
Years since first exposure	.048 (.012)	15.87	**.0001**
Years exposed	.0002 (.008)	0.00	.9797
Packyear	.003 (.002)	2.66	.1026
	MODEL EXCLUDING AGE		
Intercept	-1.646 (.231)	50.70	.0001
Years since first exposure	.076 (.009)	72.49	**.0001**
Years exposed	-.003 (.008)	.10	.7469
Packyear	.003 (.002)	3.58	.0584

Table XI
Logistic Regression Analysis of Radiologic Abnormalities

Explanatory Variable		Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept	(paronly vs. normal)	-4.203 (.557)	57.02	.0001
	(pleonly vs. normal)	-2.466 (.451)	29.86	.0001
	(parpleu vs. normal)	-5.196 (.443)	137.75	.0001
Age	(paronly vs. normal)	.054 (.015)	13.17	.0003
	(pleonly vs. normal)	.028 (.013)	4.50	.0338
	(parpleu vs. normal)	.060 (.012)	31.07	.0001
Years since first exposure	(paronly vs. normal)	-.005 (.021)	.06	.8113
	(pleonly vs. normal)	.041 (.017)	5.55	**.0185**
	(parpleu vs. normal)	.049 (.016)	9.28	**.0023**
Years exposed	(paronly vs. normal	.022 (.014)	2.33	.1265
	(pleonly vs. normal)	.001 (.011)	.002	.8911
	(parpleu vs. normal)	.013 (.016)	1.70	.1919
Packyear	(paronly vs. normal)	.013 (.014)	22.21	**.0001**
	(pleonly vs. normal)	-.002 (.003)	.39	.5320
	(parpleu vs. normal)	.014 (.010)	37.27	**.0001**

Table XII
Logistic Regression Analysis of Radiologic Abnormalities

Explanatory Variable		Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept	(paronly vs. normal)	-2.798 (.383)	53.33	.0001
	(pleonly vs. normal)	-1.78 (.310)	33.06	.0001
	(parpleu vs. normal)	-3.420 (.307)	124.50	.0001
Years since first exposure	(paronly vs. normal)	.047 (.015)	9.13	.0001
	(pleonly vs. normal)	.067 (.012)	29.29	.0001
	(parpleu vs. normal)	.113 (.012)	91.38	.0001
Years exposed	(paronly vs. normal)	.017 (.014)	1.53	.2165
	(pleonly vs. normal)	.00002 (.011)	0.00	.9982
	(parpleu vs. normal)	.008 (.010)	.53	.4660
Packyear	(paronly vs. normal)	.014 (.003)	25.23	.0001
	(pleonly vs. normal)	-.001 (.002)	.17	.6764
	(parpleu vs. normal)	.014 (.002)	42.45	.0001

Table XIII

Dyspnea on Exertion (MRC Grade 3 and Higher) and Profusion of Parenchymal Small Opacities (with and without Associated Pleural Changes)

Chest x-ray Profusion of small opacities	Parenchymal changes only			Parenchymal and Pleural changes		
	Total N	Dyspnea gr 3 & higher		Total N	Dyspnea gr 3 & higher	
		N	%		N	%
1/0-1/2	282	50	17.7	1024	199	19.4
2/1-2/3	36	8	22.2	255	88	34.5
3/2-3/4	7	1	14.3	79	39	49.4
Total	325	59*	18.2	1358	326*	24.0

* The difference in prevalence statistically significant $x^2=5.09$ $p=0.024$

Table XIV
Logistic Regression Analysis of Dyspnea

Explanatory Variable	Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept	-3.285 (.448)	53.82	.0001
Age	.024 (.010)	6.59	.0103
Years since first exposure	.012 (.012)	0.98	.3222
Years exposed	-.015 (.008)	3.50	.0615
Packyr	.005 (.002)	12.51	.0004
Parenchymal abnormlaities only	-.072 (.220)	.11	.7425
Pleural abnormalities only	-.101 (.086)	1.38	.2409
Pleural and Parenchymal abnormalities present	.244 (.106)	5.32	**.0210**
Profusion of small irreg. opacities (parenchymal abnormalities only)	.002 (.337)	0.00	.9970
Profusion of small irreg. opacities (parenchymal and pleural abnormalities)	.067 (.104)	11.22	**.0001**

Table XV
Logistic Regression Analysis of Dyspnea

Explanatory Variable	Regression Coefficient (±S.E.)	Chi-square	P-value
Intercept	-2.585 (.350)	54.42	.0001
Years since first exposure	.035 (.009)	16.03	**.0001**
Years exposed	-.018 (.008)	5.08	**.0242**
Packyr	.006 (.002)	13.08	.0003
Parenchymal abnormlaities only	-.089 (.220)	.16	.6854
Pleural abnormalities only	-.109 (.086)	1.61	.2038
Pleural and Parenchymal abnormalities present	.236 (.106)	5.00	**.0254**
Profusion of small irreg. opacities (parenchymal abnormalities only)	.00005 (.337)	0.00	.9986
Profusion of small irreg. opacities (parenchymal and pleural abnormalities)	.684 (.103)	43.73	**.0001**

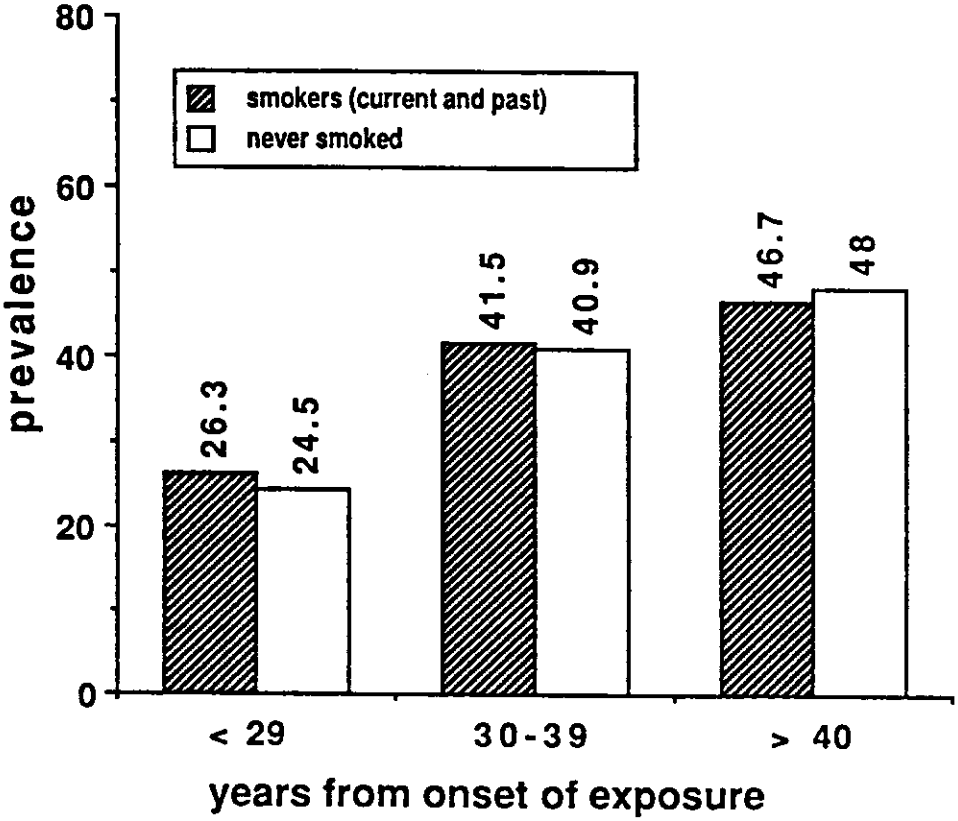

Figure 4. Diaphragmatic pleural plaques relationship with duration from onset of exposure and cigarette smoking.

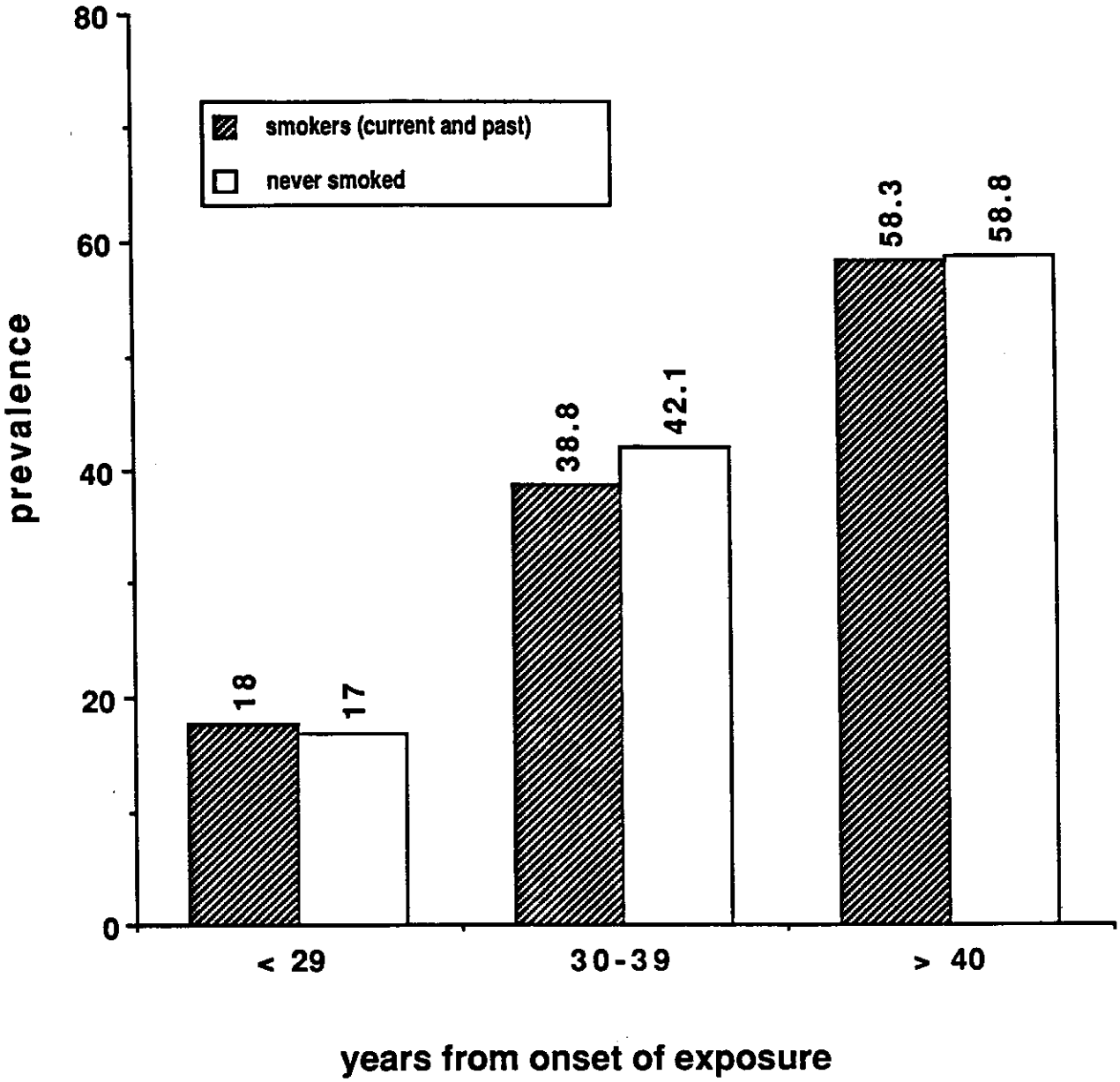

Figure 5. Pleural calcifications relationship with duration from onset of exposure and cigarette smoking.

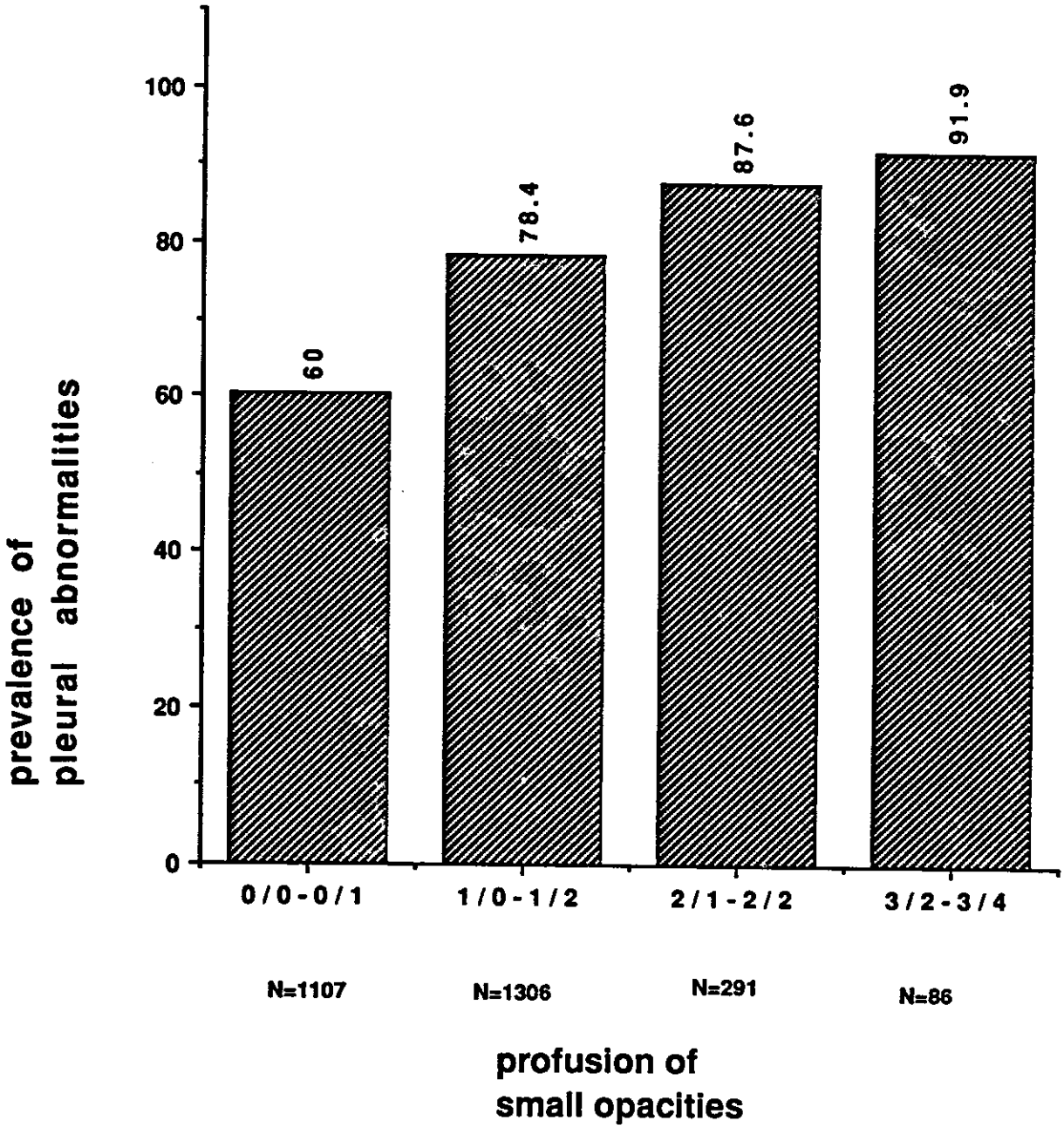

Figure 6. Relationship between interstitial pulmonary fibrosis (profusion category) and prevalence of pleural abnormalities (pleural fibrosis, plaques and calcifications).

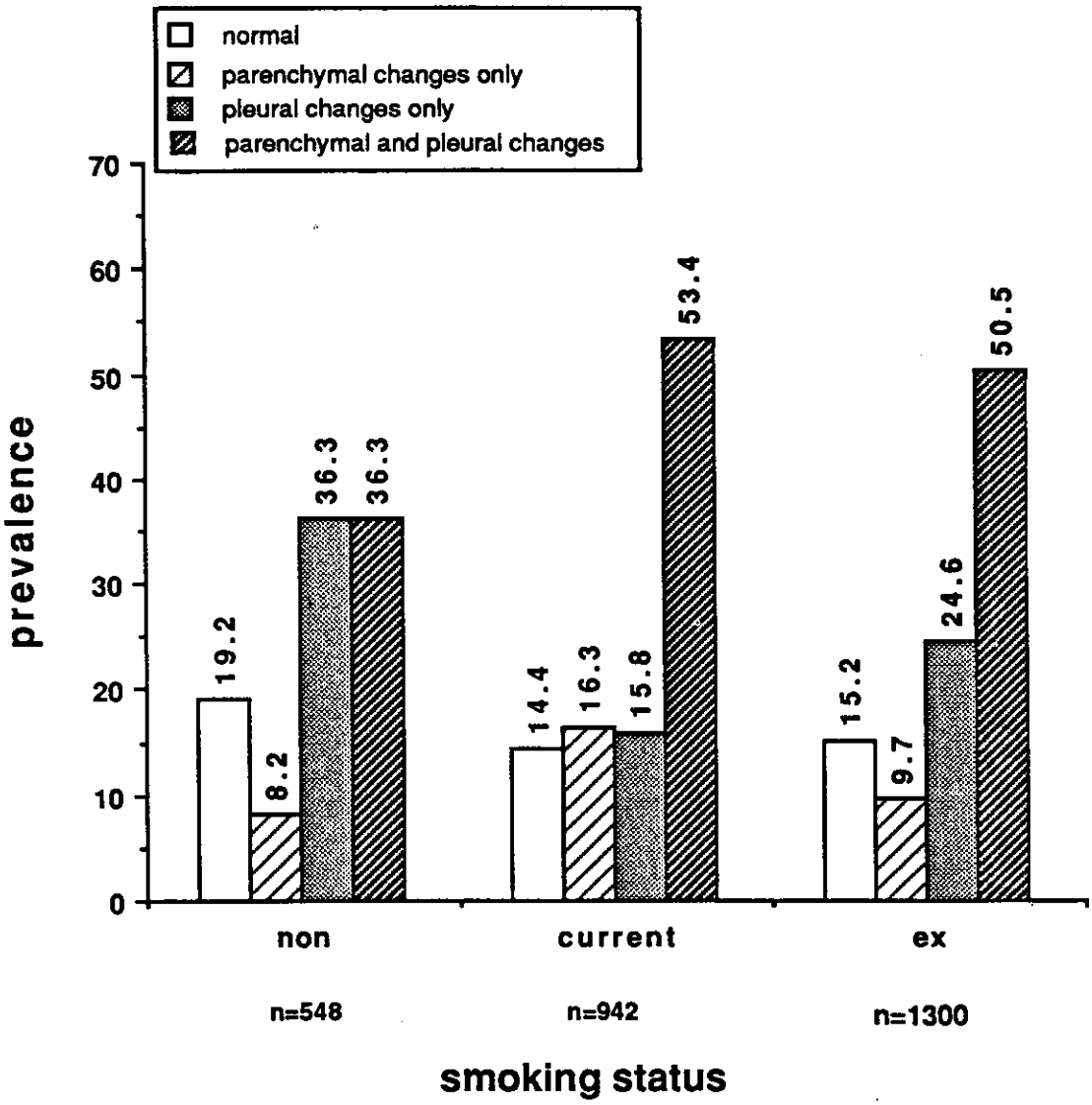

Figure 7. Distribution pattern of radiographic abnormalities by smoking category.

A STUDY ON ASBESTOS-ASSOCIATED LUNG DISEASES AMONG FORMER U.S. NAVAL SHIPYARD WORKERS

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INTRODUCTION

We have had opportunities of studying health conditions of a former U.S. Naval shipyard in Yokosuka, Japan. The examinations were carried out once a year from 1984. All were volunteers who had worked more than 30 years on an average in the U.S. Naval shipyard. The workers except two female workers, who had been engaged in office work, had been exposed to asbestos directly or indirectly. The exposure information was collected through referring to them for working environment and workshops they had belonged to. There were a few subjects who underwent the health examinations four times until 1987. The latest data for the subjects who underwent twice or more were used for the present analysis. During the 4 years there were no remarkable changes in radiographic findings. We will discuss roentgenological manifestations of effects of asbestos dust exposure on the subjects. Each chest radiograph was interpreted according to the International Classification of Radiographs of Pneumoconiosis (ILO/UC).

Distributions of Age and Years Since First Exposure of Asbestos

We studied 248 former U.S. Naval shipyard workers. They were classified into the following two groups (Tables I and II): 1) workers of group A were exposed only in the U.S. Naval shipyard; and 2) workers of group B had been already exposed in other workplaces before employment of the U.S. Naval shipyard. The number of group A workers was 148 and the number of group B was 100. The average age was 62.1 years (61.8 years for group A and 62.6 years for group B). The mean job duration in the U.S. Naval shipyard was 33.2 years (32.0 years for group A and 33.2 years for group B). The job duration of dusty work except the U.S. Naval shipyard for group B was 9.5 years on an average.

Parenchymal Fibrosis

Not only small irregular opacities characteristic of asbestos exposure, but also small nodural opacities were observed to some extent on most of the chest radiographs. It can be considered that these small opacities depended on welding, sandblasting and other dusty work in ship repair and/or building work. Therefore the development of parenchymal fibrosis was interpreted as combined profusion.

We classified all the subjects of groups A and B into 4 subgroups: 1) workers having worked almost always in ships (subgroup 1), 2) workers having had their tasks around ships and/or in factories (subgroup 2), 3) workers having worked both in ships and on shore (subgroup 3), and 4) workers having been engaged in office work (subgroup 4).

The reason why all the subjects were classified into 4 subgroups was based on different intensities of asbestos exposure. Distribution of parenchymal fibrosis by category was as follows: the number of category 1 or more in group A amounted to 136 of 148 persons or 92.0%; the number of category 1 or more in group B also amounted to 96 of 100 persons or 96.0%. 232 persons of pneumoconiosis in groups A and B comprised 119 persons of subgroup 1 (48.0%), 42 persons of subgroup 2 (16.9%), 68 persons of subgroup 3 (27.4%) and 3 persons of subgroup 4 (1.2%).

The prevalence of pneumoconiosis was highest in subgroup 1, followed by subgroup 3, subgroup 2 and subgroup 4 in this order. These data clearly reflected different exposure intensities by subgroup. On the other hand, the prevalence of category 2 was highest in group B (44 persons or 44.0%) and that of category 2 was lower in group A (38 persons or 25.7%). This fact might be related to 9.5 years' work in other workplaces before employment of the U.S. Naval shipyard.

Pleural Abnormalities

Distribution of pleural abnormalities in the subjects is shown in Tables III, IV, and V.

The prevalence of pleural abnormalities by subgroup was similar to the case of parenchymal fibrosis. Pleural abnormalities amounted to 197 of 248 persons or 79.4% and no pleural abnormalities to 51 persons or 20.6%.

The prevalence of roentgenographic pleural abnormalities by age was as follows: number of different kinds of the abnormalities was 1.5 in the age of 70 years or more (18 findings in 12 persons), 1.08 in the age of 60s (194 findings in 175 persons), 0.92 in the age of 50s (54 findings in 59 persons) and 1.0 in the age of 40s (1 finding in 1 person). The prevalence of pleural abnormalities increased with age.

Plaques

Pleural thickening of over 5 mm was adopted as the evidence of plaques in profile. En face plaques were naturally included in the data.

Table I

Distribution of Age and Years Since First Asbestos Exposure in Group A

Age	Years since first asbestos exposure (since onset of employment in US Naval shipyard)						
	<10	10-19	20-29	30-39	40-49	50≦	total
49	0	0	0	0	0	0	0
50-59	1	2	1	28	8	0	40
60-69	1	4	15	81	3	0	104
70	0	0	3	1	0	0	4
	2	6	19	110	11	0	148

Table II

Distribution of Age and Years Since First Asbestos Exposure in Group B

Age	Years since first asbestos exposure at other workplaces before US Naval shipyard						
	<10	10-19	20-19	30-39	40-49	50≦	total
49	0	0	1(1)	0	0	0	1
50-59			0(2)	3(15)	14	0	17(17)
60-69	(1)	(4)	3(5)	8(62)	63(2)	0	74(74)
70		0	1(7)	3(1)	4	0	8(0)
	(1)	(4)	5(15)	14(78)	81(2)	0	100(0)

( )=Years since first exposure in the US Naval shipyard

Table III Group A

	NO pleural abnormalities by category parenchymal fibrosis					Pleural abnormalities by category parenchymal fibrosis					
SUBGROUP	0	1	2	3	Total	0	1	2	3	Total	
1	0	4	3	0	7	3	32	19	2	56	63
2	4	4	2	0	10	0	15	7	0	22	32
3	1	9	3	0	13	3	27	4	2	36	49
4	1	1	0	0	2	0	2	0	0	2	4
Total	6	18	8	0	32	6	76	30	4	116	148

Table IV Group B

SUBGROUP	0	1	2	3	4	Total	0	1	2	3	total	
1	1	2	4	0	0	7	2	27	25	1	55	62
2	1	4	3	0	1	9	0	5	1	0	6	15
3	0	2	1	0	0	3	0	9	10	1	20	23
4	0	0	0	0	0	0	0	0	0	0	0	0
total	2	8	8	0	1	19	2	41	36	2	81	100

Table V Groups A and B

SUBGROUP	0	1	2	3	4	Total	0	1	2	3	total	
1	1	6	7	0	0	14	5	59	44	3	111	125
2	5	8	5	0	1	19	0	20	8	0	28	47
3	1	11	4	0	0	16	3	36	14	3	56	72
4	1	1	0	0	0	2	0	2	0	0	2	4
total	8	26	16	0	1	51	8	117	66	6	197	248

Table VI Group A

	Extent of Parenchymal Fibrosis				
Subgroup	0	1	2	3	total
1	3	36	22	2	63(42.6%)
2	4	19	9	0	32(21.6%)
3	1	36	7	2	49(33.1%)
4	1	3	0	0	4(2.7%)
	12	94	38	4	148(100.0%)

Table VII Group B

	Extent of Parenchymal Fibrosis				
Subgroup	0	1	2	3	total
1	3	29	29	1	62(62%)
2	1	9	4	0(1)*	15(15%)
3	0	11	11	1	23(23%)
4	0	0	0	0	0(0%)
	4	49	44	2(1)*	100(100%)

Table VIII Both Group A and B

	Extent of Parenchymal Fibrosis				
Subgroup	0	1	2	3	total
1	6	65	51	3	125(50.4%)
2	5	28	13	0(1)*	47(19.0%)
3	4	47	18	3	72(29.0%)
4	1	3	0	0	4(1.6%)
	16	143	82	6(1)*	248(100.0%)

*: Large opacities

1. Hyaline plaques

   Interval since first exposure of asbestos appeared to be the factor that determined the prevalence of hyaline plaques. On the other hand, the prevalence rate of hyaline plaques was higher in 50s and 60s age groups than in 70s group. This will be discussed later. A total number of hyaline plaques among the subjects was 76 findings (30.6%).

2. Calcified plaques

   There was no definite relationship between the prevalence of calcified plaques and interval since first exposure of asbestos. However, it was clear that the prevalence of this type of plaques increased with age. A total number of calcified plaques was 60 findings (24.0%).

   A total number of the plaques amounted to 136 findings (54.8%). The prevalence rate of the plaques became higher not only with age but also with duration of the exposure, as shown in Figure 1.

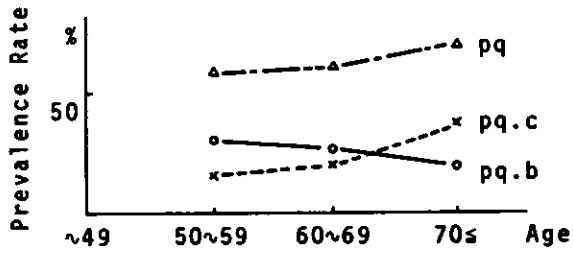

Figure 1. Prevalence of parenchymal fibrosis by exposure.

Radiographic Findings of a Control Group

Of those retired workers registered in an employment agency called "Grey Human Resources Bank" for people of 60 years or more in Yokosuka, 40 persons having not experienced occupational asbestos exposure were examined as a kind of control group in November 1987. The mean age was 67.2 years. 18 persons or 45.0% had no pneumoconiosis changes on their chest X-rays, but 22 persons or 57.0% of the subjects had pneumoconiosis of category 1. A number of pleural abnormalities except tuberculous pleuritis was 12 (30.0%), including 1 person with hyaline plaques, 1 with calcified ones and 6 with costophrenic angle obliterations. 24 persons or 60.0% had no pleural abnormalities on their chest X-rays.

DISCUSSION AND CONCLUSION

The prevalence of the former U.S. Naval shipyard workers with radiographic abnormalities characteristic of asbestos exposure was extremely higher than that of the control group.

The prevalence of parenchymal fibrosis and pleural abnormalities increased with age. Such radiographic changes were also influenced by interval since first exposure of asbestos dust.

The prevalence of pneumoconiosis was also influenced by intensities of asbestos exposure in terms of 4 subgroups.

In the age group of 70 years or more, the prevalence rate of calcified plaques was higher than that of hyaline plaques. The prevalence rate of hyaline plaques was lower in 70 years or more than in 50s and 60s age groups. These are perhaps because hyaline plaques had developed into calcified plaques.

Among the subjects, a case of lung cancer and a case of stomach cancer were found in these four years.

The subjects examined in the present study were only part of the retired workers from the U.S. Naval shipyard. Therefore, it was a tip of an iceberg that was examined by us.

As you know, the U.S. Navy has already adopted stringent occupational health and environmental protection regulations for control of asbestos. However, the Japanese Government is basically responsible for health of Japanese workers employed in the U.S. military facilities in Japan. According to the Pneumoconiosis Law and the Specific Chemical Substance Control Regulation, only those workers of category 3 or more are being followed up after retirement. We strongly insist on a revision of this legislation. For the time being, retired shipyard workers are surely important targets for the specific health examination.

ASBESTOS EXPOSURE, SMOKING AND LUNG CANCER—RESULTS OF A COHORT STUDY IN THE ASBESTOS CEMENT INDUSTRY

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INTRODUCTION

The following paper presents preliminary results of a historical-prospective cohort study which has been conducted in the oldest asbestos-cement factory of the world, in a region in which the diagnoses of death certificates rely on autopsy in every third case of death (Vöcklabruck, Upper Austria). Cohort and reference population have been described earlier.[8,10,11]

BACKGROUND

In Austria asbestos consumption relies on imports which (after exhaustion during World War II) increased to 39.583 (metric) tons in 1973[4] when 28.063 tons (70%) were used by the asbestos cement factory investigated. In 1985 approximately 18.000 tons (90%) of imported asbestos were used by this company.

In Vöcklabruck predominantly chrysotile was used (since 1895). From 1920 to 1977 also crocydolite was used in the pipe factory. Amosite (used for certain products in 1970–1986) played no role for the exposure of employees. The dust supply of asbestos in jute-sacks was stopped in 1960–1970. Open edge mills (kollergangs) were still a major source of exposure up to 1965. Most persons exposed to high levels derived from the period of increased production after 1945, when work was carried out until the mid 60's without appropriate dust removal and high-speed machines had been introduced in the finishing area. A satisfactory extraction of respirable dust was functioning since 1969 and in 1975 a new high-performance dust-suction system was put into operation.

METHODS

From 1950 we found a stabilized population and workforce, and the records for classification of individual exposures. Therefore we included in the cohort all persons employed (for at least 3 years) in the asbestos cement plant Vöcklabruck from 1950–1981. Before 1969 (the decisive year in improving dust situation) 82% of our cohort members had been employed, most of them around 20 years of age, but older persons were also given jobs, especially in the period of full employment. Details of exposure- and age-distributions have been reported.[11] Individual exposures were estimated since 1973 from personal records on duration of exposure at different workplaces, dust level estimations until 1965, dust measurements mainly by conimeter method until 1975 and by personal air samplers and membrane filter method.[1] Independent of the exposure study of the factory carried out by the safety engineers in cooperation with the Austrian Dust and Silicosis Control Office, we sent trained interviewers to all cohort members who had left the plant after 1950 and were still alive in 1982, to obtain data on occupational exposures and smoking by standardized questionnaire. The coding of tobacco exposure was carried out similarly to that of asbestos exposure according to time periods, changing number of cigarettes smoked and tar content. The minimum information "smoker, non-smoker, ex-smoker" was also obtained from deceased persons via relatives and (independently of this) from four work mates.

Completely separated from the exposure enquiries was the follow-up investigation with the government registration offices and the determination of the cause of death with the aid of the death registries, physicians and pathologists.

RESULTS

Of the 2816 persons eligible for the study we found 2155 alive and 540 dead in 1987. 121 persons had been lost, mainly by emigration. Altogether, 51,218 personyears were available for analysis. These included 24,897 observation years above the 40th year of life which are relevant for the assessment of the risk of lung cancer. Table I shows official diagnoses on underlying cause of death from 535 death certificates used for comparison with the general population mortality. The best available information on the main cause of death after enquiries in hospitals, pathological institutes and social insurance are given in brackets. They were used for comparisons within the cohort. Subsidiary causes of death or other important diseases which were diagnosed besides the main disease leading to death are listed under "additional diagnosis."

Lung cancer (SMR 1.7) and stomach cancer (SMR 1.5) were found significantly more frequent than in the general population of Upper Austria corresponding in age and sex. Also pleural and peritoneal cancer occurred more frequently and even if taking into account that some of them turned out to be non-mesotheliomas (e.g., pleuritis carcinomatose in adenocarcinoma of the lung, carcinosis peritonei in pancreatic carcinoma) the 5 cases from best available information (4 of them verified by autopsy and histology) showed an overly high relative risk, since the corresponding rates of histologically verified cases in Austria were found orders of

Table I

STEM-Analysis of Fibrous Adsorption Granulates Containing Sepiolite and Attapulgite

Four samples consisting of relatively long fibres and 1 sample composed of comparatively short fibres were selected; in previous studies (by the use of X-ray diffraction and differential thermoanalysis) 3 of these samples proved to be sepiolite and 2 to resemble attapulgite.

STEM-analysis of adsorption granulates							
main mineralogical component	presence of long fibres	fibre dimensions median values of 100 fibres any length*)			fibre concentr. of any length*)		L ≥ 5 um**)
		L [um]	D [um]	L/D	$x10^9$ [F/mg]	n	$x10^6$ [F/mg]
sepiolite	+	1.0	0.03	26	135	25	12.7
sepiolite	+	1.1	0.04	28	111	54	12.2
attapulgite	+	1.3	0.05	29	71	26	26.4
attapulgite	-	0.7	0.03	20	110	25	1.8
sepiolite	++	1.0	0.03	29	120	68	1240

*) STEM, 29000x
**) TEM, 10000x

magnitude lower.[5,9] Pneumoconioses are registered mainly as additional causes of death. Of the illnesses of the circulatory system the deaths from cor pulmonale are of interest in this connection. The cause of death could not be determined in 5 cases (0.9%). The overall mortality was not significantly higher than in the corresponding general population of Upper Austria (SMR 1.04).

Table II shows the increase in lung cancer in comparison to this age- and sex-corresponding reference population (4 census results and migration-corrected interpolations from births and deaths in years between censuses have been used for calculation of expected). If the calculation of expected values takes smoking habits into account, however, an adjusted SMR of 1.04 results, which is not significantly raised. For this adjustment the age- and sex-specific results of microcensus on smoking in Upper Austria[6] and a lung cancer risk factor 8 times as high as that for non-smokers was used for the smokers.[13] From the lower part of Table II no higher lung cancer rate can be seen in workers who cumulated more than 25 fibers/ml.year. Lung cancers observed in persons with lower cumulative doses included also 2 cases who died after only 4 years of employment.

A life table analysis with best available diagnoses showed the expected differences between smokers and non-smokers: the overall probability of survival of smokers was 1.7% at the end of observation and 64.1% at age 65 (95% confidence interval: 59.6–68.2%). Survival of never smokers was 7.9% and 67.1% at age 65 (confidence 58.9–75.3%). Survival from lung cancer was 78.4% for smokers (93.7% at age 65, confidence 91.0–96.4) and 96.0% for never smokers (99.2% at age 65, confidence 97.7–100.0). These differences were statistically significant (Poisson, $p < 0.01$). The same life table calculation for groups with different asbestos exposures (according to cumulative doses and according to exposure class at begin of work) revealed no systematic relation to the probability of surviving from lung cancer.

DISCUSSION

The excess lung cancer mortality which we found in asbestos cement workers compared to the general population of corresponding age and sex could be explained by the higher tobacco consumption of the workers compared to the general population. An additional influence of asbestos exposure could not be proven up to now. From our sample size we can exclude a relative lung cancer risk of more than 1.34 (Poisson, one-sided). This result is in agreement with those from similar factories and industries using mainly chrysotile[2,12,13] without extreme exposures. Figure 1 compares cumulated doses of 56 deaths from lung cancer and mesothelioma with those of 464 non asbestos associated

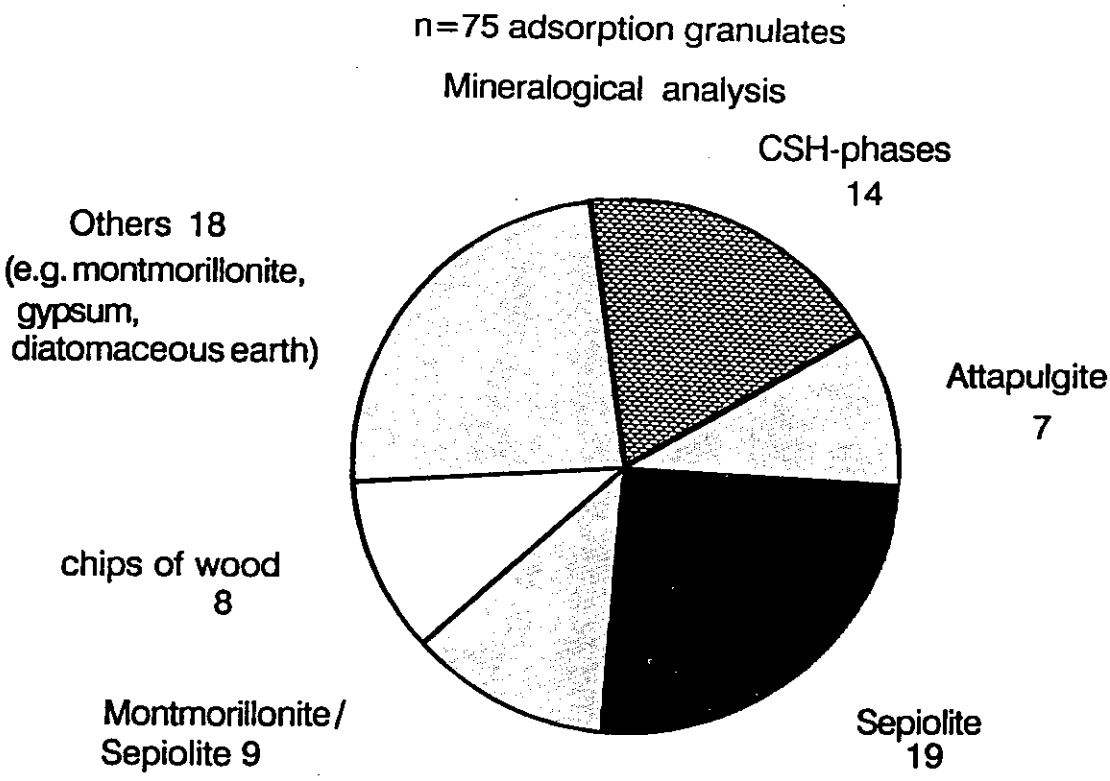

Figure 1. Mineralogical composition of 75 commercially available adsorption granulates used in animal keeping.

deaths. The resulting cumulative frequencies were nearly identical up to a cumulative dose of 50 fibers/ml.year. This result would be compatible with a threshold for lung cancer between 25 and 100 fibers/ml.year[3] and a nongenotoxic action of asbestos on the bronchial epithelium. For mesothelioma, however, asbestos could be a complete carcinogen with much lower fiber doses sufficient to initiate the tumor. The lowest dose we registered in a woman who was only exposed from 1958–1963 to an average of approximately 1 fiber/ml (range up to 10 fibers/ml), corresponding to 5 fibers/ml.year. But she was exposed to crocidolite in pipe production (exposure level staged as "medium"). In a nested case-control study the 4 deaths from mesothelioma verified by autopsy had been matched to 16 controls by sex and as close as possible by year of first employment, length of employment and year of birth. Crocidolite exposure level (disregarding duration) was staged without knowledge of the diagnosis from existing records. All verified mesotheliomas were found to have had medium to high crocidolite exposure whereas controls alive in 1987 had negligible to medium exposures (Table III). The crocidolite exposures of the 4 mesothelioma cases and the 16 matched controls were statistically significant (Miettinen $Chi^2 = 2.8125$, $p < 0.05$). This result is compatible with other studies[2,4] and also with our own experience from a population-based case-control study on 120 verified mesotheliomas in Austria.[5,9] Our results confirm that the absolute risk of mesothelioma in asbestos-cement production is low, but that there is a high relative risk, probably associated with the use of crocidolite.

According to latency we expect some more cases of mesothelioma in our cohort and cannot exclude the occurrence of asbestos induced lung cancers in the near future, because 148 surviving members of our cohort have had exposures of more than 50 fibers/ml.year. But from present working conditions at much lower levels of chrysotile (the use of crocidolite in pipe production has been stopped completely) we do not expect any more occupational cancer in the asbestos cement industry.

SUMMARY

In the oldest asbestos cement factory a historical prospective cohort study set up in the 1970s included all persons employed in 1950-1981 and for at least 3 years. From 2816 persons eligible for the study record-based estimates and measurements of dust and fibers and interview based smoking histories were used to calculate person-related exposures over time. After observation of 51,218 personyears and registration of 540 deaths underlying causes were compared with the regional population on the basis of death certificates.

Lung cancer in asbestos cement workers was raised (SMR 1.7), but not significantly after adjustment for age- and sex-specific smoking habits (SMR 1.04). Using the best available evidence (including autopsy records) 52 deaths were assigned to lung cancer and 5 to mesothelioma. Their cumulated dose-distribution differed from cases not associated with asbestos, for exposures >50 fibers/ml.years. Life table analyses confirmed the predominant influence of smoking on lung cancer.

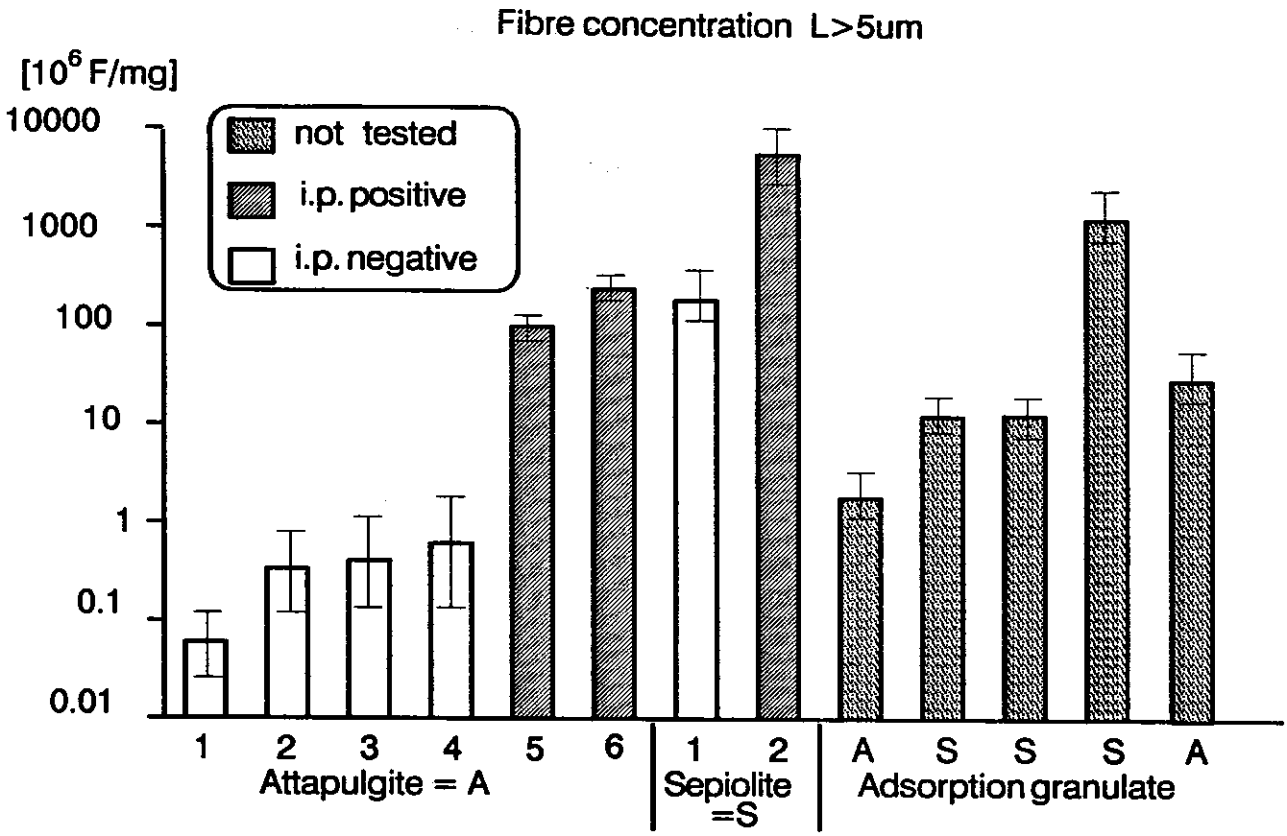

Figure 2. Number of fibres with a length of L ≥ 5 μm in 5 selected adsorption granulates as revealed by TEM at a magnification of 10,000x. Comparison of samples of attapulgite (Georgia 1, 2, Mormoiron 3, Lebria 4, Torrejon 5, Cacéres 6) and sepiolite (Spain 1, Finland 2) examined in animal experiments, c.f.[4]

Mesothelioma was associated with the use of crocidolite in pipe production. A relative lung cancer risk of >1.3 can be ruled out in the given dose-range with predominant use of chrysotile.

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ACKNOWLEDGEMENTS: .This work was supported by the Austrian Science Research Fund (Fonds zur Fördermy der Wissensdioftlichen Forschung).

Tables II and III not provided.