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THE ROLE OF COAL MINE DUST EXPOSURE IN THE DEVELOPMENT OF PULMONARY EMPHYSEMA

V. Vallyathan,* F. H. Y. Green,‡, P. Brower† and M. Attfield†

*Division of Health Effects Laboratory, NIOSH, Morgantown, WV, U.S.A.;
†Division of Respiratory Disease Studies, NIOSH, Morgantown, WV, U.S.A.; and ‡Department of Pathology, University of Calgary, Calgary, Alberta, Canada T2N 4N1

INTRODUCTION

Coal miners have long been recognised to be at increased risk for several forms of pneumoconioses, including macules, nodules, progressive massive fibrosis (PMF) and silicosis, as well as for other chronic lung diseases (Kleinerman *et al.*, 1979). Although focal emphysema is recognised as an integral part of the lesion of simple CWP (Kleinerman *et al.*, 1979), the relationship between coal mining and disabling emphysema is an issue that still sparks considerable scientific debate and controversy (Hurley and Soutar, 1986; Gee and Morgan, 1979; Seaton, 1990).

In this study we examine the relationship between severity of emphysema and years of employment in underground coal mining, years smoked, retained dust in the lung, and CWP. Our findings show a positive association between coal mining, and emphysema and are similar to previously reported autopsy studies from Europe and Australia (Ruckley *et al.*, 1984; Leigh *et al.*, 1994; Lyons *et al.*, 1981; Cockcroft *et al.*, 1982).

METHODS

Population

The study group consisted of 266 underground coal miners autopsied at the Beckley Southern Appalachian Regional Hospital, Beckley, West Virginia from 1957–1971. All miners had at least 1 year of underground bituminous coal mining experience and had worked in various mines within a 100 mile radius of Beckley. Available information consisted of the following: age at death, smoker (never, ever), years smoked, underground coal mining tenure and cause of death. A comparison population of 75 non-miners comprised 25 (13 male, 12 female) autopsies from the same hospital during the same period of time and a series of 50 autopsies (all male) collected and processed in a similar manner at the University of Vermont from 1972–1978. The latter were derived from a population of Medical Examiner deaths. At autopsy, whole left lungs (except when trauma or neoplasm precluded their use) were removed and cannulated through the bronchus and infused with a 4% buffered formaldehyde solution at a constant pressure of 30 cm of water for 1 h. A sagittal slice of the whole lung was embedded in a gelatin solution according to the procedure of Gough *et al.* (1952) and semi-thin sections

(~ 200 μm) were cut on a sledge microtome. Tissue blocks were taken for histologic examination from representative areas of the right and left lungs.

Pneumoconiosis classification and grading

The whole lung sections were evaluated by two investigators (VV and FHYG) according to the diagnostic criteria established by the joint committee of the College of American Pathologists and the National Institute for Occupational Safety and Health (Kleinerman *et al.*, 1979). Macules, micronodules, macronodules and PMF were each graded on a four-point scale of increasing severity within the whole lung section by both readers independently, in random order without knowledge of historical information, radiographic classification, or autopsy diagnosis. The grades were based on a series of reference standards established and scored for CWP prior to the grading process (Hu *et al.*, 1990). Items of disagreement were subsequently resolved by consensus with reference to the standard lung sections and the consensus scores were used in the analyses.

Emphysema grading

The severity of emphysema (emphysema index) in whole lung sections was graded by two pathologists (VV and FHYG) using a set of photographic standards (Thurlbeck *et al.*, 1974) in conjunction with a 10 segment grid (Saito and Thurlbeck, 1995). Each zone was graded as though it were the whole lung using the photographic standard panel to give a maximum score of 100 for each zone and a total maximum score of 1000 for each lung.

Analysis of the lungs for total dust, total mineral, coal and silica

For a subgroup of 63 miners, a 1.5 cm slice of lung adjacent to the whole lung section had been analysed for total dust, coal dust, total mineral and free silica using standardized protocols. Data were expressed as mg(dust)g^{-1} of dry lung.

Statistical analysis

Statistical analyses including Wilcoxon rank score test, *t*-test, Pearson's correlation coefficient and graphical techniques were used to explore the relationships between the primary variable emphysema and the following: years smoked, years worked underground, and retained dust for miners (never-smokers and ever-smokers) and non-miners (never-smokers and ever-smokers).

RESULTS

Population characteristics

Tables 1 and 2 show the breakdown of the cases used in this study by age at death, underground mining tenure and smoking history. The overall average age of the non-miner (51.7) group was less than that of the coal miner (66.6) group (Table 1). However this difference was not statistically significant. There was, however, a statistically significant difference in age between the 50 medical examiner cases from Vermont (49 ± 16 years) and the 25 West Virginia non-miners (57 ± 14 years) and the 266 miners (66.1 ± 10.1 years).

Table 1. Demographic characteristics of study groups

	Coal miners	Non-miners
Number of cases	266	75
Age at death	66.6 ± 10.1*	51.7 ± 15.8
Years of underground mining	32.1 ± 10.6	—
Years smoked	36.9 ± 14.5	28.2 ± 15.1

* Means ± standard deviation. Differences between groups were not statistically significant.

Table 2. Study groups: distribution by smoking status

Group	Never smokers *N*	Ever smokers *N*	Total
Non-miners	14	61	75
Miners	41	225	266
Total	55	286	341

Table 3. Distribution of emphysema by mining and smoking

Group	Never smokers	Ever smokers	*P*-Value
Non-miner	46 ± 15.5	152 ± 18.4	0.0038*
Miner	295 ± 36.4	392 ± 16.3	0.0015†
P-Value	0.0001*	0.0001*	—

* Wilcoxon rank score test. † *t*-test.

Relationships between emphysema index, mining tenure and smoking

The distribution of emphysema scores for the miners and non-miners by smoking status is shown in Figs 1 and 2. The distribution of emphysema index appears to be influenced independently by smoking and years underground (figure not shown). Centriacinar (including focal) emphysema was the most prevalent type of emphysema in both never-smokers and ever-smokers.

The mean emphysema index and its standard error for non-miners and miners by smoking status are shown in Table 3. The emphysema index was significantly greater for ever-smokers than for never-smokers within the mining group (*P*-values < 0.005) and for miners compared to non-miners within the smoking group (*P*-value = 0.0001). The effect of smoking and mining on the emphysema index appears additive in this basic model.

Table 4 shows the correlation between emphysema and years worked underground and years smoked for miners. For miners the relationship between emphysema and years of underground mining was stronger for ever-smokers ($r = 0.45$) than for never-smokers ($r = 0.18$).

Relationship between pneumoconiosis and emphysema index

A majority of miners had macules (97%), 67% had micronodules, 41% had macronodules, 27% had PMF and 13% had silicosis. There was a good overall correlation between emphysema index and severity of CWP by pathologic grading ($r = 0.51$, $P = 0.0001$).

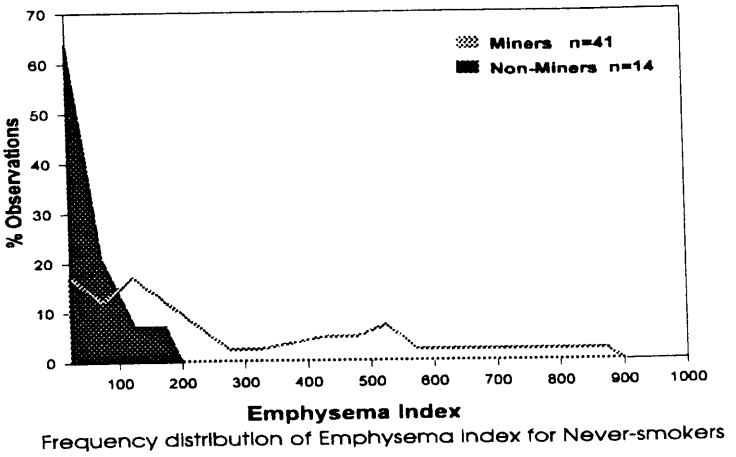

Fig. 1.

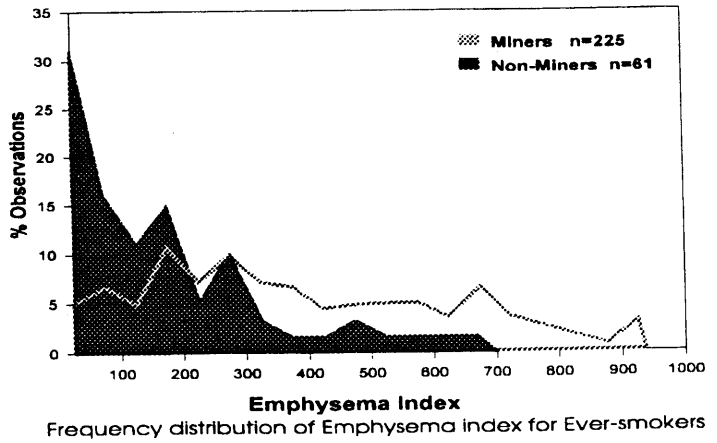

Fig. 2.

Table 4. Correlation between emphysema index and years worked underground and years smoked for miners

		Years worked underground	*P*-Value		Years smoked	*P*-Value
Emphysema	All miners	0.21	0.0006	All ever-smokers	0.27	0.0003
	Never-smoke miners	0.45	0.0028	Non-miner smokers	0.28	0.0692
	Ever-smoke miners	0.18	0.0080	Miner ever-smokers	0.18	0.0411

Table 5. Relationship between emphysema index and lung dust burden for 63 miners

Lung dust characteristics	mg gm^{-1} dry lung (mean ± SE) Ever-smokers	Never-smokers	Overall correlation	*P*-Value
Total	7.1 ± 0.58	6.9 ± 1.5	0.34	0.006
Coal	4.4 ± 0.50	5.1 ± 1.2	0.46	0.0002
Total mineral	2.8 ± 0.31	1.8 ± 0.46	−0.09	0.49
Silica	0.20 ± 0.02	0.18 ± 0.03	0.09	0.47

Relationship between emphysema index and retained dust for 63 miners

Overall, emphysema score was significantly correlated with total dust ($P = 0.006$) and coal dust ($P = 0.0002$) but not with total minerals and silica (Table 5).

DISCUSSION AND CONCLUSION

In this study we show that the severity of emphysema in coal workers is associated with mining tenure, retained coal dust, severity of pneumoconiosis and years of smoking. Our findings are consistent with the results of autopsy studies on coal miners from the United Kingdom (Cockcroft *et al.*, 1982; Lyons *et al.*, 1981; Ruckley *et al.*, 1984) and Australia (Leigh *et al.*, 1994). Also they are consistent with epidemiologic studies of dusts other than coal dust in showing that an association with airways obstruction and emphysema (Oxman *et al.*, 1993). Plausible mechanisms for mineral dust induced emphysema have been advanced; these implicate increased protease activity and oxidative inactivation of α-1 antitrypsin in its pathogenesis (Rom *et al.*, 1990).

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