A COMPARISON OF THE PREVALENCE OF COAL WORKERS' PNEUMOCONIOSIS AND RESPIRATORY IMPAIRMENT IN PENNSYLVANIA BITUMINOUS AND ANTHRACITE MINERS

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INTRODUCTION

The opinion has often been expressed that anthracite miners are more prone to develop pneumoconiosis and respiratory disability than are their bituminous counterparts. Yet this belief is difficult to prove, and most previous studies in which the respiratory status of anthracite and bituminous miners have been compared have suffered either from faulty selection or poor participation. Thus, when Lieben and colleagues [1] made their prevalence survey of pneumoconiosis in central Pennsylvania, they obtained only 25% participation; in Eastern Pennsylvania, the same workers obtained a 60% response,[2] but even the latter can hardly be regarded as satisfactory. Comparison between groups such as these is fraught with danger. On the other hand, the United States Public Health Service and Bureau of Mines have recently started a long term study of the prevalence of progression of coal workers' pneumoconiosis (CWP), and to date miner participation has been excellent. The data collected in this study permit valid comparison of the prevalence of CWP and the various respiratory impairments seen in Pennsylvania bituminous, as opposed to anthracite, miners.

MATERIAL AND METHODS *

In 1969, the United States Public Health Service and Bureau of Mines of the Department of the Interior selected for study 31 coal mines widely scattered throughout the United States. The mines were chosen to represent different geographical regions, different coal seams, and different mining methods. Further criteria for inclusion were that the mine should have at least 100 miners, that it should have an expected working life of about ten years, and that retrospective dust exposure data should be available as often as possible. Unfortunately, no anthracite mine met this last criterion.

Each miner employed at these 31 mines was asked to undergo a limited

* Mention of brand names or products does not constitute endorsement by the United States Public Health Service.

medical examination, consisting of the administration of the Medical Research Council of Great Britain short questionnaire on chronic bronchitis,[3] an occupational history, and standard postero-anterior and lateral chest films. In addition, after two practice maneuvers, three forced expiratory volume maneuvers were performed. They were recorded as flow volume loops on a recording oscilloscope and then photographed with a Polaroid camera.[4] From these data, the forced expiratory volume in one second (FEV_1) the forced vital capacity (FVC), and peak and midflows were derived. The best of the three values of the various indices was accepted. The total lung capacity (TLC) was determined by Barnhard's radiographic method,[5,6] and the residual volume (RV) was calculated by subtracting the forced expiratory volume (FVC) from the TLC. Normal spirometry values used were those of Kory and others,[7] and total lung capacity and residual volume were predicted from the short equation of Needham and his colleagues.[8] Three observers independently interpreted the radiographs according to the UICC classification.[9] A consensus was accepted in regard to major categories; however, in the occasional instance when all three observers disagreed, (about 5%), a fourth reader was called in. Under these circumstances, a consensus was always obtained. All statistical tests were performed at the 95% level of confidence.

A total of 1455 miners from six Pennsylvania bituminous coal mines took part in the study. Participation was more than 96%. Three of the mines were located in the Johnstown area of central Pennsylvania, and the other three were in western Pennsylvania. Those in the former region mine coal of a fairly high rank, whereas those in western Pennsylvania mine the Pittsburgh seam of lower rank coal.[10] In addition, two anthracite mines were included in the study. Both were located in eastern Pennsylvania. A total of 518 anthracite miners were examined. Despite the fact that at the time of the medical survey, one of the two anthracite mines was on strike, the response was over 85%. In many instances, the miners came several miles from their homes to the portal in order to participate.

RESULTS

The mean age for the two groups was very similar (the anthracite miners were only marginally older). The average number of years spent underground was also similar. Nevertheless, pneumoconiosis was much more common among the anthracite miners than among the bituminous miners. The higher prevalence of CWP in the anthracite miners as a group was almost entirely a consequence of the proportionately greater number of subjects with PMF, i.e., 14.1% as compared to 2.4%. This difference is highly significant.

TABLE 1 shows that the prevalence of simple pneumoconiosis for the two groups is roughly equivalent: 44% for the bituminous miners and 46% for the anthracite miners. This apparent similarity in the percentage of miners with simple pneumoconiosis as a whole is misleading in that the proportion of miners within each category of simple pneumoconiosis (i.e., 1, 2, and 3) is quite disparate. Thus, the percentage of anthracite miners with categories 2 and 3 simple pneumoconiosis, and incidentally with PMF, is significantly greater than those with category 1. Conversely, a greater percentage of the bituminous miners have either category 0 or 1. This finding suggests that once an anthracite miner develops category 1, he is more likely than the bituminous miner to progress to categories 2 and 3.

TABLE 1

CHARACTERISTICS OF BITUMINOUS AND ANTHRACITE MINERS

	Radiographic Category					
	0	1	2	3	PMF	Total
Bituminous						
Number	775	462	168	15	35	1,455
% of total	53.3	31.8	11.5	1.0	2.4	100.0
Mean age	46	50	52	52	54	48
Mean years underground	19	24	28	33	32	22
Anthracite						
Number	208	119	94	24	73	518
% of total	40.2	23.0	18.1	4.6	14.1	100.0
Mean age	48	50	54	55	55	51
Mean years underground	17	23	29	34	33	24

When the prevalence of bronchitis is compared in the two types of miners, it is apparent that a substantially greater proportion of anthracite miners have cough and sputum (TABLE 2). Possible nonoccupational explanations for this disparity are the differing smoking habits and ages of the two groups; however, the difference in age between the two mining groups was very slight, and there were fewer smokers among the anthracite miners than among the bituminous miners. Turning to the prevalence of other symptoms such as wheeziness, the latter was present in 32% of the anthracite miners as compared to 16% of the bituminous miners. The percentages of miners with complaints of either moderate or severe dyspnea were 29 for the anthracite workers and 16 for the bituminous.

Most of the spirometric and lung volume data shown in TABLES 3 and 4 are expressed as a percentage of their predicted value, thus standardizing for age and height. Overall, the mean FEV_1, FVC, and RV were significantly

TABLE 2

BRONCHITIC BITUMINOUS AND ANTHRACITE MINERS

	Radiographic Category					
	0	1	2	3	PMF	Total
Bituminous						
No.	139	112	46	2	6	305 of 1,455 (21%)
Percentage of smokers 47%, exsmokers 30%						
Anthracite						
No.	67	48	33	12	30	190 of 518 (37%)
Percentage of smokers 41%, exsmokers 30%						

TABLE 3

MEAN VALUES FOR SPIROMETRY AND LUNG VOLUMES OF BITUMINOUS MINERS

Mean	Radiographic Category					All Categories
	0	1	2	3	PMF	
($FEV_{1.0}$ obs/pred)%	95	93	93	94	89	94
(FVC obs/pred)%	102	100	99	101	102	101
(RV obs/pred)%	114	125	129	145	122	120
(TLC obs/pred)%	105	108	109	114	109	107
($FEV_{1.0}$/FVC)%	74	72	73	72	67	73
($FEV_{1.0}$/FVC)% (nonobstructed; 1,012 of 1,455=70%)	78	77	77	77	76	78
($FEV_{1.0}$/FVC)% (obstructed; 443 of 1,455=30%)	62	63	64	60	61	62

different for the two groups, the FEV_1 and FVC lower and the RV higher in the anthracite miners. In the anthracite miners, the FEV_1 and FVC tend to decline with increasing category, a change that is not apparent in the bituminous miners. These overall differences, though not significant for every radiographic category, all show the same trend. Thus, the FEV_1 differs significantly between the anthracite and bituminous miners in subjects with category 2 and PMF; the FVC, in categories 0, 2, and PMF; and the RV, in categories 0, 1, and PMF. The disparity between the two groups in the subjects with PMF is accounted for by a higher proportion of anthracite miners having the B and C stages of complicated pneumoconiosis. The data for the spirometric values are shown in TABLES 3 and 4 and are graphically represented in FIGURE 1. As would be expected, the RV tends to drop when the subject develops PMF.

The mean (FEV_1/FVC)% for the anthracite and bituminous was 72 and 73%, respectively. If the two groups are subdivided into obstructed and nonobstructed subjects according to whether their (FEV_1/FVC)% was greater or less than 70%, it can be seen that obstruction is found more commonly in

TABLE 4

MEAN VALUES FOR SPIROMETRY AND LUNG VOLUMES OF ANTHRACITE MINERS

Mean	Radiographic Category					All Categories
	0	1	2	3	PMF	
($FEV_{1.0}$ obs/pred)%	93	91	88	86	78	89
(FVC obs/pred)%	99	98	94	94	89	96
(RV obs/pred)%	126	134	137	148	144	133
(TLC obs/pred)%	108	110	109	114	110	109
($FEV_{1.0}$/FVC)%	73	73	73	71	66	72
($FEV_{1.0}$/FVC)% (nonobstructed; 334 of 518=64%)	78	78	79	80	76	78
($FEV_{1.0}$/FVC)% (obstructed; 184 of 518=36%)	61	63	60	62	59	61

the anthracite miners. This difference can be explained only partially by differing smoking habits, since 57% of the obstructed anthracite miners were smokers, as compared to 53% of the obstructed bituminous miners.

Discussion

It has long been suggested that the disease that anthracite miners develop differs from that seen in the bituminous coal miner.[1,2] Nonetheless, both

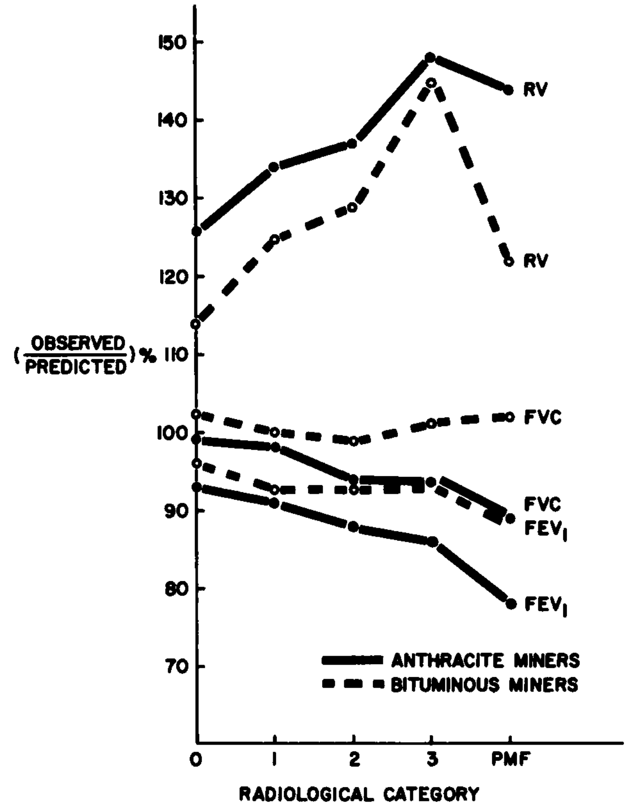

Figure 1. Mean spirometry and lung volumes of anthracite and bituminous miners.

Gough and Heppleston in their extensive studies of CWP maintain that there is no essential pathological difference between CWP, no matter in which country or continent it is found.[11] Although this conclusion may well be true, CWP has been shown to occur with greater frequency in the anthracite mines of Pennsylvania and South Wales than in other geographic areas. This phenomenon has variously been attributed both to the silica content of the coal mined and its rank.[10] Although there is some circumstantial evidence to incriminate both factors, too many other variables have been in effect to permit a final opinion as to the role of either. Of paramount importance in the development of CWP is dust exposure, and in this connection, only the European countries and South Africa have had an adequate dust sampling program for a significant length of time. In the United States, no opinion can be ventured as to whether the increased prevalence of CWP in the anthracite mines is likely to result from the greater dustiness of these mines.

There are few studies in which pulmonary function and respiratory symptoms have been compared in bituminous and anthracite miners. Our study shows that although the overall prevalence of simple CWP is similar in the anthracite and bituminous miners, fewer anthracite miners have category 1, and many more have categories 2 and 3. This disparity cannot be accounted for either by age or by years spent underground, since these factors were almost identical for categories 2 and 3 simple CWP in both types of miners. The finding thus suggests that once an anthracite miner has developed category 1, he is more likely to progress to categories 2 and 3 than is a bituminous miner. In short, the development of category 1 simple CWP has more significance in anthracite than in bituminous miners and is of more serious import. The greater prevalence of categories 2 and 3 in the anthracite miners and the more rapid transition from category 1 to 2 and 3 explain the greater prevalence of PMF. Not only has it been shown that the risk of developing PMF is much greater when the miner has category 2 or 3 simple CWP,[12] but those subjects who progress rapidly from category 1 to categories 2 and 3 are likewise at greater risk than those who progress more slowly.[13]

Our study also shows that the anthracite miners' ventilatory capacity sometimes decreases to a greater extent than does that of the bituminous miner, whereas his residual volume usually increases significantly. These changes indicate that obstructive airway disease occurs more frequently in anthracite miners and that it cannot be accounted for by differences in cigarette smoking. We feel that the differences in ventilatory capacity and the prevalence of respiratory symptoms are related to the miner's occupation. Unfortunately, as indicated above, no reliable data are available on the levels of dust that have prevailed over the past 20 years in either the anthracite or bituminous mines, and indeed it was not until 1970 that a dust sampling program came into operation in the United States. It occurred to us, however, that perhaps more anthracite miners than bituminous worked at the face and/or on transportation as their main occupation; in reality the figures were 34 and 9% respectively, as compared to bituminous miners, whose figures were 54 and 15% respectively. This finding suggests that something other than the amount of respirable dust to which a miner is exposed is responsible for the differences mentioned above. In this connection, not only might the constituents and the chemical composition of the inhaled coal dust have an effect, but particle size distribution could also play a role. Thus, although it is widely accepted that CWP is produced by particles of between 0.5 and 5 microns,[14] it might well be that particles of approximately 1 micron are more harmful than particles of 4 to 5 microns, and that although two mines may have essentially similar respirable dust concentrations over a given period, the proportion of smaller particles, i.e., around 1 micron, might be significantly greater in one mine than in the other.

Neither can the larger particles, especially those of more than 10 microns, be ignored. It has been shown that airway resistance can be partitioned into central and peripheral components, and that 80% or more of the total resistance is to be found in the central airways.[15] Moreover, conventional forced expiratory volume maneuvers are influenced mainly by changes in the central resistance, and, conversely, significant increases in the peripheral resistance can occur in the presence of a normal spirogram. The coal macule, the pathological lesion produced by respirable coal dust particles, is situated around the first to second divisions of the respiratory bronchiole; [11] exerting an effect on the peripheral airways only, it thus is unlikely to be picked up by conventional spirometry. Previous investigations carried out in our laboratory have shown, first, an increased residual volume in miners with simple CWP in the absence of large airways obstruction,[16] and second, frequency dependence of compliance in some miners with simple CWP and an absence of large airways obstruction. Both of these findings suggest the presence of small airways obstruction. On the other hand, larger particles, i.e., those above 10 microns, are deposited mainly in the larger airways.[14] The symptoms of bronchitis are related to excessive mucus production by the mucous glands of the larger airways; it is noteworthy that the anthracite miners in our series had more bronchitis than did their bituminous counterparts. These symptoms, and the slightly lowered ventilatory capacity, might be related to an industrial bronchitis produced by coal dust inhalation; if so, it is likely that the larger particles are responsible. It only remains to be pointed out that presently dust measurements are directed entirely at assessing the exposure of the miner to respirable dust. It cannot be assumed, however, that because the respirable dust fraction is at an acceptable level, the larger dust particles are also at an acceptable level, or vice versa. Further investigation along these lines is needed.

Summary

As part of a larger national study, the prevalence of radiographic evidence of coal workers' pneumoconiosis and of respiratory impairment in a group of 1455 bituminous coal miners from six mines was compared to that present in a group of 518 miners from two anthracite mines. The bituminous mines were located in central and western Pennsylvania, and the latter were located in eastern Pennsylvania. The prevalence of pneumoconiosis as a whole (60%) and progressive massive fibrosis (14%) was significantly higher in the anthracite miners than in their bituminous colleagues (47% and 2.4%, respectively). In addition, the prevalence of bronchitis was higher in the anthracite miners; likewise, their residual volume was significantly increased. These differences could not be explained by differences in years spent underground or by differing smoking habits. It was concluded that there is an agent, as yet unidentified, in the working environment of the anthracite miner that puts him at a greater risk than his bituminous counterpart.

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