



Severe Occupational Pneumoconiosis Among West Virginian Coal Miners

One Hundred Thirty-eight Cases of Progressive Massive Fibrosis Compensated Between 2000 and 2009

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Background: Miners inhale dust at work and are at a risk for coal workers pneumoconiosis (CWP), a preventable and potentially fatal lung disease. After regulations were implemented in the 1970s, declines were reported in both dust levels and the prevalence of simple and advanced CWP until about 2001, when despite stable reported dust levels, disease levels sharply increased.

Methods: A structured, retrospective chart review was performed to describe the demographics and disease progression for 138 coal miners with progressive massive fibrosis (PMF) whose claims were approved by the West Virginia State Occupational Pneumoconiosis Board between January 2000 and December 2009.

Results: PMF, a complication of CWP, developed in 138 West Virginian coal miners at a mean age of 52.6 years after an average of 30 years work tenure. The time of progression averaged 12.2 years from the last normal chest radiograph until PMF was detected. Lung function declined sharply in both smokers and nonsmokers, averaging 87 mL/y for FEV₁ and 74 mL/y for FVC. The board has confirmed 21 deaths in this group. The most common job activities were operating continuous-mining machines (41%) and roof bolting (19%). Virtually all of these miners' dust exposures occurred after the implementation of current federal dust regulations.

Conclusions: Contemporary occupational dust exposures have resulted over the past decade in rapidly progressive pneumoconiosis and massive fibrosis in relatively young West Virginian coal miners, leading to important lung dysfunction and premature death. *CHEST* 2011; 139(6):1458-1462

Abbreviations: CWP = coal workers pneumoconiosis; PMF = progressive massive fibrosis; WVSOPB = West Virginia State Occupational Pneumoconiosis Board

Coal miners inhale dust while working. If exposures are excessive, lung clearance mechanisms are overwhelmed, and dust particles accumulate over time, causing airflow limitation and the development of interstitial lung disease known as coal workers pneumoconiosis (CWP).¹ The interstitial changes are

manifest on chest radiographs as small pneumoconiotic opacities (< 10 mm in diameter) (Fig 1).

Progressive massive fibrosis (PMF), also called complicated pneumoconiosis, is recognized when the fibrotic nodules of CWP, silicosis, and certain other pneumoconioses coalesce and expand to form solid lesions that measure ≥ 10 mm on the chest radiograph (Fig 1). As PMF worsens, adjacent lung tissue retracts toward the lesions, typically in the upper-lung zones. Alveoli and blood vessels are destroyed, and airways

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become distorted as lung volume is lost. Airflow limitation, hypoxia, pulmonary hypertension, and death from respiratory or heart failure can ensue, even without further dust exposure.

In 1969, the Coal Mine Health and Safety Act became law, and since 1972, coal mines in the United States have been required to comply with a permissible exposure limit of 2.0 mg/m³ for respirable dust.² The goal of the dust limit was to decrease the incidence of CWP as well as prevent the advanced and lethal stages of CWP from developing in the miners. Mine operators are required to monitor respirable dust exposure levels to demonstrate compliance with the dust limit and to offer periodic radiographic health surveillance to miners who work underground. After 1969, dust levels reported for enforcement purposes declined. As anticipated, radiographic surveillance indicated a progressive decline in the prevalence of advanced CWP among miners who had started working after implementation of the act.^{3,4} The decline continued until approximately 2001, when an increase in all types of CWP began to be observed.⁵ Clusters of rapidly progressive and advanced CWP, including PMF, have been observed recently in Kentucky, Virginia, and West Virginia.⁶⁻⁸

The West Virginia State Occupational Pneumoconiosis Board (WVSOPB) began in 2000 to monitor the annual proportion of claimants with PMF lesions on chest radiographs and noted an apparent progressive increase, although the incidence of cases was not monitored prior to 2000. CWP appeared to be progressing to PMF more frequently among coal miner claimants, at an earlier age, and at a more accelerated rate than previously observed. The goal of this report is to describe the pattern and progression of disease based on WVSOPB records available for 138 West Virginia underground coal miners with PMF whose pneumoconiosis claims were awarded between 2000 and 2009.

MATERIALS AND METHODS

The WVSOPB examines miners based on the current regulations and statutes in West Virginia. Miners who submit claims often undergo repeated evaluations over a period of years. Board records include demographic data, work histories, limited medical histories and physical examinations, and chest radiographs and spirometry. As part of each evaluation, a classification of the miner's radiographs for evidence of pneumoconiosis was done by WVSOPB physicians. This investigation is based on a retrospective chart review of case files for all miners who were compensated for CWP with PMF between 2000 and 2009. The data collection received approval (#08-12-2107) on December 4, 2008, from the Charleston Area Medical Center Institutional Review Board. Demographic data (age when PMF was diagnosed, height, weight, sex, and race), work history, smoking history, and spirometry data were abstracted. No information was available about the total hours worked per year or use of personal protective devices. Percent predicted was calculated for FEV₁ and FVC.⁹ Procedures

and equipment for all lung function studies met American Thoracic Society standards.¹⁰ PMF cases were initially confirmed and compensation awarded by the WVSOPB. Later, for the purposes of this study, each chest radiograph for the cases subsequently underwent a separate interpretation using the International Labour Office classification of pneumoconiosis by one of the investigators (E. L. P.), who is a National Institute for Occupational Safety and Health-approved B reader and is not affiliated with the WVSOPB.¹¹ To be included in the case series, each individual must have worked as an underground or surface coal miner, and the most recent chest radiograph must have been interpreted by both the WVSOPB and the investigator as showing large opacities consistent with PMF. For both CWP and PMF, we recorded the miner's age and the calendar year of the first chest radiograph available to the WVSOPB showing the abnormality as well as the number of years the miner reported respiratory symptoms prior to radiographic recognition of PMF.

A subgroup of 43 miners had at least one normal chest radiograph (International Labour Office category 0/0 or 0/1) in the WVSOPB files before the radiograph demonstrating PMF. The pace of development of radiographic PMF and the rate of lung function decline were assessed in this subgroup. The time interval between the last normal chest radiograph and the first radiograph showing opacities consistent with PMF was used to estimate an upper limit of the time to develop PMF. Development of PMF from other subcategories of CWP could not be assessed because of small numbers. Declines in FEV₁ and FVC during development of PMF were evaluated for each of the 31 miners in the subgroup with complete results. The spirometry result when the miner last had a normal chest radiograph was subtracted from the value when the radiograph first showed PMF, and these differences were then divided by the time interval between the tests to determine rates.

RESULTS

PMF was first observed radiographically in the 138 miners between 1989 and 2009 at an average age of 52.6 years (Table 1). Before PMF developed, the miners had worked, on average, 30 years and had experienced 8 years of respiratory symptoms (dyspnea, cough, sputum production, or wheezing). Work histories of the cases revealed no important nonmining dust exposures. Two mining activities accounted for more than one-half of all primary jobs worked; 41% of the cases operated continuous-mining machines, and 19% performed roof bolting, which involves drilling through rock and inserting metal bolts and plates to prevent roof falls. The WVSOPB has a record of 21 deaths in this group by December 2009, although other fatal cases may have occurred that were not reviewed by the board.

In the subgroup of 43 miners in whom radiographic progression could be determined, age (52.6 years) and tenure (30.6 years) were nearly identical to the overall group. The time between the last normal chest radiograph and the first radiograph with massive fibrosis was as little as 5 years and averaged 12.2 years. Using a published definition,⁶ pneumoconiosis was rapidly progressive in all these cases. Longitudinal spirometry results are shown in Table 2. Sharp lung function

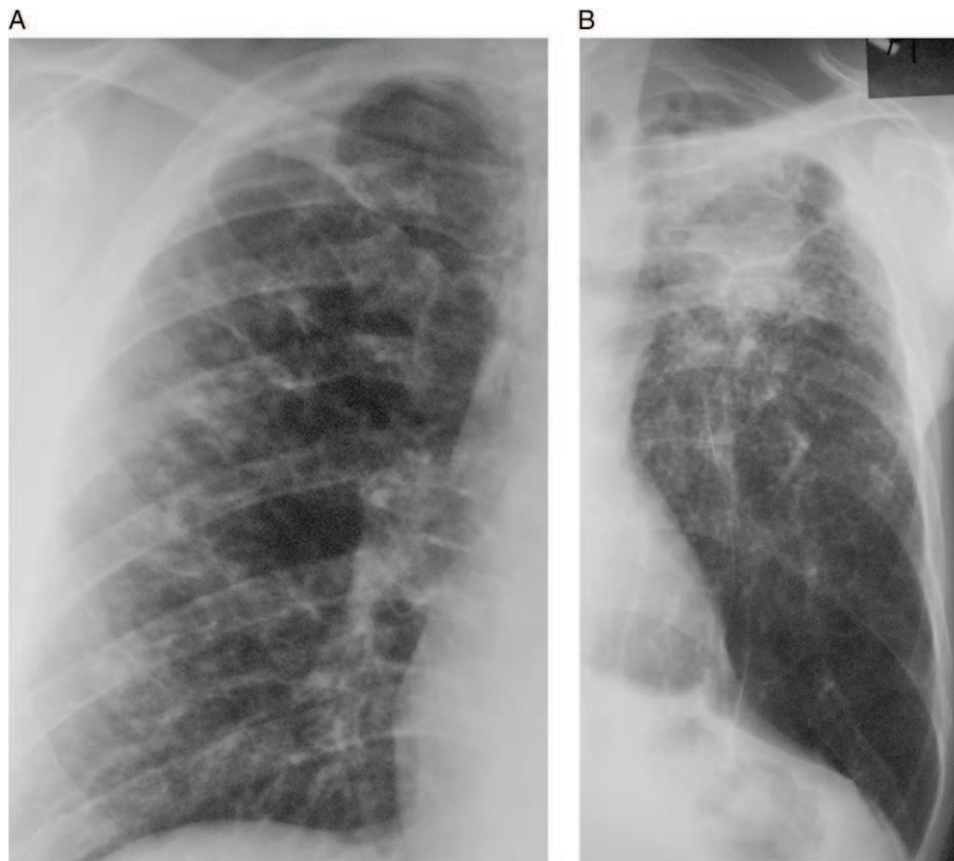


FIGURE 1. Example radiographs from a group of 138 West Virginian coal miners. A, Simple pneumoconiosis. B, Progressive massive fibrosis.

losses occurred between the date of the last normal radiograph and the first showing massive fibrosis; the rate of decline averaged 87 mL/y for FEV₁ and 74 mL/y for FVC. The accelerated declines were similar in ever smokers (n = 18) and never smokers (n = 13).

DISCUSSION

CWP is a potentially life-threatening and entirely preventable disease caused by excessive inhalation of coal mine dust.^{1,12,13} This report summarizes findings from 138 West Virginian coal miners recently compensated for CWP with PMF, expanding limited prior knowledge of the rapidly progressive form of CWP.^{7,8} The average interval from a normal chest radiograph to massive fibrosis was 12 years, and the miners' lung function declined at a markedly accelerated rate compared with declines observed in nonsmoking (37 mL/y) and smoking (48 mL/y) nonminers of a similar age.¹⁴ This case series cannot determine whether disease prevalence is increasing over time, but a recent report confirms a rising prevalence of PMF among US coal miners, with a greater increase in those working at small mines.¹⁵ The current findings indicate that severe occupational lung disease develops

in many current US coal miners during their productive working years and provide evidence that the rapidly progressive form of pneumoconiosis often leads to important lung impairment. Although the report includes all miners compensated by the WWSOPB for confirmed PMF during the past decade, it likely underestimates the actual number of West Virginian miners who developed severe occupational lung disease during this period. Surveillance chest radiographs from 2005 and 2006 showed evidence of pneumoconiosis in >14% of underground West Virginian coal miners with at least 20 years of tenure.¹⁶ Between 1996 and 2002, approximately 67,000 coal miners worked underground in the United States, including 18,000 in West Virginia.⁴

The mine environments that caused disease in these miners were virtually all covered by the 1969 Coal Mine Act. This act established a legal limit for exposure to coal mine dusts, initiated an agency dedicated to enforcement, and provided a health monitoring program to track effectiveness. Among 32,174 experienced miners (eg, with at least 20 years underground tenure) who had monitoring chest radiographs in 1970 to 1974, 29.1% had evidence of CWP, whereas by 1995 to 1999, only 3.2% of the

Table 1—Descriptive Information for 138 West Virginian Coal Miners With PMF

Variable	Median	Range	Mean
Age at PMF, y	53	40-77	52.6
Year of PMF recognition	2003	1989-2009	2003
Smoking history, pack-y ^a	15	0.5-67.5	18.4
Years of symptoms ^b	6.5	0-25	8.1
Mining tenure, y	30	7.5-47	29.9
FEV ₁ , L (% predicted) ^b	2.85 (77.5)	0.87-4.25 (25-114)	2.79 (74.3)
FVC, L (% predicted) ^b	4.22 (86.3)	1.67-6.23 (32-125)	4.08 (84.3)
FEV ₁ /FVC ratio, % ^b	69.2	26.6-90.1	67.8
Years to PMF (n = 43) ^c	12	5-27	12.2

PMF = progressive massive fibrosis.

^aAmong 81 (59%) of 138 ever smokers.

^bAt first chest radiograph showing PMF.

^cUpper limit of time to develop PMF from a normal chest radiograph.

5,810 experienced miners showed CWP, an 89% decline in the tenure-related risk of pneumoconiosis.^{4,5} However, recent years have seen increases in both disease prevalence and years of potential life lost from CWP, a measure of premature mortality.^{5,13} Our current report documents the occurrence of disabling and fatal disease resulting from work in putatively safe environments.

Authorities have hypothesized explanations for the observed reversal of miners' health protections.^{6,13,17} Dust levels reported for enforcement purposes from US mines have not increased during the past decade, although the accuracy and representativeness of these dust measurements have been questioned.^{5,7,18} High ongoing dust exposures, up to four to five times permissible limits, have recently been documented in research reports from US coal mines.¹⁹ Current approaches to monitoring and enforcing limits on respirable silica in coal mines also have been criticized as insufficient.²⁰ Mining equipment and techniques have changed since 1969 and could conceiv-

ably affect the particle sizes or composition of mine dust. Progressively longer work shifts²¹ have increased lung dust deposition; however, no data on work hours were available for these miners. Recent studies have indicated considerably higher-than-expected disease prevalence, severity, and progression among miners in the central Appalachian mining region comprising eastern Kentucky, southwestern Virginia, and southern West Virginia.⁶⁻⁸ Coal seams are typically thinner in this region, requiring more disturbance of adjacent silica-bearing rock. Silica is known to be more toxic than coal and causes a greater inflammatory and fibrotic response in the lung. Radiographic shadows consistent with silicosis increasingly are being recorded, and the increase in these shadows has been seen primarily in miners from the central Appalachian region.²²

Opportunities for disease prevention also can be missed when miners fail to participate in screening programs to detect CWP in earlier stages. Although it is required for miners to be offered a screening chest radiograph every 5 years, miner participation recently has averaged only about 31%. Among 37 miners reported in 2007⁸ with advanced CWP, all had worked for periods of ≥ 10 years where no screening chest radiograph was obtained. Barriers to miner participation in screening programs need to be identified and surmounted. However, the relatively short interval (12 years) between the last normal radiograph and the identification of PMF in the reported cases raises concerns regarding the effectiveness of radiographic surveillance for detecting rapidly progressive pneumoconiosis. Lung function monitoring also is currently recommended, although not required, for coal miners.²³ The rapidity of the functional declines observed during the development of PMF in the miners suggests spirometry monitoring may have utility in this setting.

Although the increase in advanced CWP and PMF apparently began in about 2001, it has been recognized for a number of years that the current exposure limit is not adequate to fully protect miner lung health. In 1995, National Institute for Occupational Safety and Health recommended that the permissible limit for respirable coal mine dust exposure be decreased to 1 mg/m³,²³ but this recommendation has not been implemented.

CONCLUSIONS

This case series documents that contemporary work exposures have resulted over the past decade in the development of PMF in relatively young coal miners, leading to significant lung dysfunction and premature death. Rapidly progressive and severe occupational

Table 2—Decline in Lung Function During the Development of PMF (n=31)

Value	Mean
Δ FEV ₁ , L ^a	0.98
Δ FVC, L ^b	0.87
Rate of decline, mL/y	
FEV ₁ (all)	87
FVC (all)	74
FEV ₁ (ever smokers) ^c	74
FVC (ever smokers) ^c	58
FEV ₁ (never smokers) ^d	106
FVC (never smokers) ^d	101

See Table 1 for expansion of abbreviation.

^a Δ FEV₁ = FEV₁ value measured at last normal chest radiograph - value at first radiograph showing PMF (median, 0.80 L; range, 0.19-2.21 L).

^b Δ FVC = FVC value measured at last normal chest radiograph - value at first radiograph showing PMF (median, 0.69 L; range, 0.06-2.47 L).

^cn = 18.

^dn = 13.

lung disease is continuing to develop among US coal miners. To prevent future dust-induced illnesses and deaths among miners, industry and regulatory agencies must improve the effectiveness of coal miner health protections.

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Author contributions: *Dr Wade:* developed the project protocol, case abstraction form, and analysis plan; worked on abstracting and tabulating the case data; and drafted the manuscript.

Dr Petsonk: contributed input to all stages of the project, including managing institutional review board approval, providing the confirmatory International Labour Organization radiographic interpretations, and writing, review, and approval of the manuscript.

Mr Young: contributed the interface of the project protocol with WVSOPB records, supported case file and radiograph retrieval, supervised file management during file reviews, and reviewed and approved the manuscript.

Dr Mogri: contributed assistance in case file reviews and data abstraction and reviewed and approved the manuscript.

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