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Current Review of Pneumoconiosis Among US Coal Miners

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Abstract

Purpose of Review—This review summarizes recent research on pneumoconiosis in coal workers following the identification of the resurgence of this disease among US coal miners in the early 2000s. We describe the impact of this research and how this has led to increased public attention, benefitting affected miners.

Recent Findings—The latest research shows that the prevalence of pneumoconiosis, including progressive massive fibrosis, continues to increase, especially in central Appalachia. Contributing factors may include mining of thin coal seams or cutting rock to access coal, which may expose miners to coal mine dust with a higher content of silica and silicates than in the past.

Summary—The impact of recently implemented changes, such as the reduced occupational exposure limit for respirable coal mine dust and the introduction of continuous personal dust monitors, will likely take years to appropriately evaluate.

Keywords

Pneumoconiosis; Coal miners; Environmental health

Introduction

The Federal Coal Mine Health and Safety Act of 1969 (Coal Act) begins with the declaration: “the first priority and concern of all in the coal mining industry must be the health and safety of its most precious resource—the miner.” [1] The principal goals of the Coal Act were to reduce the amount of combustible coal dust in underground mines, which had been responsible for numerous catastrophic mine explosions, and to reduce respirable coal mine dust, which caused substantial respiratory morbidity among coal workers, including from coal workers’ pneumoconiosis (CWP), commonly referred to as “black lung.” The Department of Interior’s Bureau of Mines was tasked with inspecting

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underground mines for compliance with dust standards, a task that is now the responsibility of the Mine Safety and Health Administration (MSHA) within the Department of Labor. The Coal Act also mandated the creation of an x-ray surveillance program for coal miners, to be administered by the Department of Health, Education, and Welfare (now the Department of Health and Human Services (DHHS)). Within DHHS, the National Institute for Occupational Safety and Health (NIOSH) has administered this program since 1970, now called the Coal Workers' Health Surveillance Program (CWHSP). Radiographic data from the CWHSP has also allowed NIOSH to study risk factors for pneumoconiosis and monitor national pneumoconiosis trends for nearly 50 years. [2]

The CWHSP offers chest radiographs at no cost to coal miners at regular intervals during their career. Extended exposure to the dust that is generated in the process of extracting coal can cause interstitial fibrosis of the lungs that can be visualized by chest radiography. An important purpose of the CWHSP's radiographic surveillance is early detection of dust-induced interstitial lung disease (pneumoconiosis) in working coal miners, a spectrum of disease now known to include CWP, silicosis, mixed dust disease, and dust-related diffuse fibrosis and preventing progression to more severe forms of pneumoconiosis through reduction or elimination of future exposure to coal mine dust. [3, 4]

The prevalence of pneumoconiosis among miners participating in CWHSP declined considerably in the decades after the Coal Act, consistent with the reduced coal mine dust standards mandated by this Act, but there has been a resurgence of the disease since the late 1990s (Fig. 1). [5••, 6] In 2014, MSHA issued a final rule designed to further reduce miners' exposure to respirable coal mine dust. [7] The rule also directed NIOSH to expand screening services offered by the CWHSP to include spirometry (a type of lung function test), since coal mine dust can cause chronic obstructive pulmonary disease (COPD), which is not reliably detected by chest radiography. [3, 4] It also extended Program eligibility to include surface coal miners, who are also at risk for pneumoconiosis. The CWHSP is unique to occupational health—coal miners are the only US workforce for which industry-wide occupational respiratory disease data are systematically collected. Given the nearly half-century-long history of the CWHSP, the troubling resurgence of severe pneumoconiosis, and recent regulatory reforms, now is a good opportunity to reflect on contemporary scientific studies of pneumoconiosis among US coal miners. This review describes the prevalence of pneumoconiosis among coal miners, including underground, surface, and former coal miners; primary and secondary prevention for this disease; measures of disease severity, including mortality and lung transplants; the role of accurate radiograph classification by B Readers; and other respiratory conditions caused by coal mine dust exposure in coal miners.

Prevalence of Pneumoconiosis in Working Underground Coal Miners

Recent prevalence studies of working coal miners in the USA have used data collected by NIOSH through the CWHSP. [8, 9] Recognizing that radiography does not differentiate between the spectrum of coal mine dust–induced interstitial lung diseases, for surveillance purposes, these studies have defined a case of CWP as the presence of small and/or large opacities identified on a coal miner's chest radiograph based on International Labour Office (ILO) classification system guidelines. [10] After decades of declining prevalence of pneumoconiosis among underground coal miners, likely resulting from enactment and enforcement of the Coal Act, [11] the national prevalence has increased since the late 1990s. [5••, 12, 13] This trend has been most pronounced in the central Appalachian bituminous coal mining region including eastern Kentucky, southwestern Virginia, and West Virginia, as noted in Fig. 1. [3, 5••, 13–17]

A 2018 study found that the national prevalence of pneumoconiosis in long-tenured (at least 25 years of experience) working miners exceeded 10%. In central Appalachia, 21% of long-tenured miners had radiographic evidence of pneumoconiosis. [5••] During the same period, NIOSH data have also shown that the prevalence of progressive massive fibrosis (PMF; defined as a chest radiograph with the presence of one or more large [> 1 cm] opacities) (Fig. 2), has increased sharply. [12, 18••] Following near-eradication in the 1990s, the prevalence of PMF, the most severe form of pneumoconiosis, in long-tenured central Appalachian coal miners, reached 3.2% in 2012 and exceeded 5% by 2014, the highest level on record. Although contemporary rates of pneumoconiosis and PMF are highest in central Appalachia, surveillance of working coal miners has identified pneumoconiosis and lung function impairment in each US coal mining region, among both underground and surface coal miners. [15] During 2005–2015, the prevalence of pneumoconiosis in the eastern USA, excluding central Appalachia, was 3.4%, compared to 1.7% in the western USA and 0.8% in the interior coalfields.

Data collected through the CWHSP have made it possible to study potential determinants of pneumoconiosis in US coal miners. [19] In reviewing these studies, it is important to remember that exposure to coal mine dust is the sole cause of pneumoconiosis in coal miners. Thus, epidemiological studies which assess correlates of exposure with pneumoconiosis must be viewed with the understanding that these correlates serve as surrogates for the respirable dust generated through the process of mining coal. The presence of pneumoconiosis and abnormal lung function assessed by spirometry has been found to be associated with working in a small mine (defined as 50 or fewer employees), [14, 20] low seam height (defined as less than 43 in. [21]), [16] miner age, mining tenure (Fig. 1), coal rank, and region (a surrogate for coal rank, mine size, and seam height). [22] Identification of these factors has allowed for more directed surveillance outreach efforts to at-risk groups and additional studies using data sources other than the CWHSP. [18••, 23, 24]

The recent studies of pneumoconiosis using CWHSP data have clearly demonstrated increased prevalence and severity of pneumoconiosis in working coal miners throughout the USA, and these findings are robust in terms of selection factors that could affect prevalence estimates. [25] These observations are also reflected in studies using independent data sources including national- and center-based lung transplant registries, medical records at clinics, state and federal disability compensation data, and state and federal accident and illness reporting data, which will be discussed in the remaining sections.

Primary Prevention of Pneumoconiosis: Monitoring and Controlling Coal Mine Dust Exposures

Because there is no cure for pneumoconiosis, minimizing exposure to coal mine dust is the most effective way to limit morbidity and mortality associated with the disease. Federal rules specify that in underground coal mines, engineering controls should be the primary method for minimizing miners' exposure to airborne respirable dust. Administrative and personal protective measures may also be used, where indicated. NIOSH published a handbook, *Best Practices in Dust Control in Coal Mining*, to describe effective engineering controls for reducing miners' exposures to respirable coal mine dust. [26]

In 1995, NIOSH published a criteria document providing a scientific basis for an updated recommended exposure limit (REL) for respirable coal mine dust of 1.0 mg/m^3 as a timeweighted average (TWA) concentration for up to 10 h/day during a 40-h workweek and recommended adherence in coal mines to the NIOSH REL for respirable crystalline silica of 0.05 mg/m^3 as a TWA concentration for up to 10 h/day during a 40-h workweek. [27] In 2016, as specified by the 2014 MSHA final rule, the long-standing permissible exposure limit (PEL) for respirable coal mine dust in underground coal mines was reduced from a maximum 8-h shift average of 2.0 mg/m^3 to a full-shift average of 1.5 mg/m^3. The exposure limit is reduced if the respirable quartz content of respirable coal mine dust exceeds a full-shift average of 100 μg/m^3, as specified in the 2014 MSHA final rule. [7, 28] The rule also made a number of changes to how coal mine dust exposures are measured, including increased sampling frequency in higher dust areas and added requirements for using continuous personal dust monitors (CPDMs) in high-risk mining occupations. CPDMs generate real-time dust measurements for the wearer, and results can be transmitted to MSHA more rapidly than traditional sampling methods. According to federal data, operator compliance with dust standards has been high for decades, with > 99% compliance since the PEL was reduced. [29–31] The preamble to the 2014 MSHA rule highlighted the agency's intent to conduct a retrospective study, beginning in February 2017, "to assess the impact of the Dust rule on lowering coal miners' exposures to respirable coal mine dust to improve miners' health." Pneumoconiosis is usually a disease of long latency, and conducting an adequate assessment of the effectiveness of the rule in improving health outcomes for miners will require many years of observation and study.

Within the context of high overall compliance with dust standards, the resurgence of pneumoconiosis in central Appalachia has spurred research on regional differences in coal mine dust characteristics. Johann-Essex and colleagues collected respirable dust samples from Appalachian coal mines, and identified significant differences in dust characteristics by sub-region and by sampling location within the mine. [31] In contrast to samples collected from northern Appalachian coal mines, samples from thinner-seam mines in central Appalachia contained higher percentages of quartz and silicates, which the authors noted was consistent with cutting more rock.

In 2016, Congress directed NIOSH to arrange a study by the National Academies of Science, Engineering, and Medicine (NAS) to "assess monitoring and sampling approaches for informing underground coal mine operators' decision making regarding the control of miner exposure to respirable coal mine dust." The NAS study concluded that effective coal mine dust control measures are readily available and have the potential to protect miners' health, and it made a number of recommendations for improving monitoring practices and assessing the impact of changes in mining practices. [30]

Secondary Prevention of Pneumoconiosis

To assure that primary prevention efforts are effective in preventing disease, secondary prevention (screening to detect disease at an early stage) must be a component of any comprehensive system of preventive medicine. For coal miners, periodic assessments are key to early identification of radiographic disease and/or respiratory impairment, when steps might be taken to prevent more severe manifestations of the disease. Participation in the CWHSP is not mandatory, and, historically, participation rates for working underground coal miners have fluctuated between 25 and 40%. [32] Coal miners who participate in the CWHSP and are found to have radiographic evidence of pneumoconiosis are entitled to a legal right to work in an environment with average dust concentrations below the applicable federal standard. This program, known as Part 90, enables miners to continue working with enhanced dust exposure protections. [33] These enhanced protections are achieved through more frequent monitoring of Part 90 miners, and can be applied through implementation of engineering controls at their existing job, or through transfer to a less dusty area at the mine site, while retaining employment and pay protections. Miners are not required to exercise their Part 90 rights, and during 1986–2016, only 14.4% of 3547 eligible US coal miners did so. Miners in central Appalachia were significantly less likely to exercise Part 90 rights compared to those in other US coal mining regions (13.1% vs. 17.3%). [34]

Although secondary prevention was strengthened with the 2014 MSHA final rule and the subsequent NIOSH enhancements to medical screening for coal miners, [35, 36] important challenges remain, including suboptimal participation in radiographic surveillance and in the Part 90 program. [37] In 2018, the U.S. Senate added an amendment to the 2019 federal budget [38] that required NIOSH to provide a report to Congress which "identifies and describes potential barriers that limit active and non-active coal miner participation" in the CWHSP. Through a public request for information (RFI) posted to the Federal Register, [39] NIOSH solicited and received feedback from a variety of stakeholders representing industry and labor interests. These stakeholders identified a number of potential barriers to participation including problems with access to approved testing facilities, privacy concerns, perceived job loss and fear of reprisal, disincentives for early detection, and mistrust in chest radiograph interpretation.

Although challenges to comprehensive medical monitoring of coal miners persist, advancements in the last decade have improved opportunities for secondary prevention. These include targeted active surveillance efforts through NIOSH mobile screening, and expansion of medical screening to include surface coal miners, respiratory symptom assessment, and pulmonary function testing. Recent social media campaigns and news reporting have heightened awareness of the importance of secondary prevention efforts.

Pneumoconiosis in Surface Coal Miners

Surface miners comprise approximately half of the US coal mining workforce. Prior to 2014, they were not entitled to participate in the CWHSP. However, prior research had identified increased risk for silicosis in surface coal miners, particularly drillers. [40, 41] Using the CWHSP mobile unit, NIOSH conducted targeted outreach during 2010 and 2011, screening more than 2000 surface coal miners. Radiographic evidence of pneumoconiosis was identified in 2% of participating miners, a majority of whom had never worked underground. The prevalence of pneumoconiosis among central Appalachian surface miners was nearly three times that of miners from other regions, similar to the geographic clustering observed in underground miners. Twelve surface miners were identified with PMF, nine of whom had never worked underground. [42] Each of these surface miners identified with PMF worked for a majority of their careers as drillers or driller/blasters (Fig. 3), occupations that, despite advances in technology, continue to experience excessive silica exposures according to compliance dust measurements. [43] Two of these miners progressed from a normal radiograph to PMF in less than 11 years. The pathological evaluation of previously biopsied lung tissue from a third miner revealed a high burden of respirable silica and silicate particles. The severe pneumoconiosis identified in these miners was likely primarily silicotic resulting from exposures to respirable crystalline silica generated by drilling blast holes during surface mining activities.

Pneumoconiosis in Former Coal Miners

The CWHSP provides working coal miners with respiratory health screening. Until recently, comparatively less has been systematically reported on the respiratory health of former US coal miners who had left the industry for reasons such as retirement. During the last decade, NIOSH conducted targeted outreach to former miners using the CWHSP mobile unit. Participating former coal miners were found to have significantly higher prevalence of pneumoconiosis and lung function impairment when compared to working miners. [44]

Since 2016, the largest clusters of severe pneumoconiosis among current and former coal miners reported in the scientific literature have been identified in clinics serving US coal mining communities. In eastern Kentucky, a single community radiology practice identified 60 cases of PMF among former miners during January 2015–August 2016. [18••] In southwestern Virginia, 416 cases of PMF, 88% of which were in former coal miners, were identified at a single clinic network during a four year period. [23] A high proportion of these miners had rounded (r-type) opacities, category B or C large opacities (> 5 cm), and mining tenures of less than 20 years, all signals of exceptionally severe and rapidly progressive pneumoconiosis.

Among miners applying for benefits through the Federal Black Lung Benefits Program (BLBP), there were 4679 unique PMF cases during 1970–2016, with 2474 identified since 1996. Eighty-four percent of these miners last worked in Kentucky, Pennsylvania, Virginia, or West Virginia. [45] Among miners applying for benefits through BLBP since the year 2000, 39% did not participate in CWHSP screening while they were employed. [46]

Pneumoconiosis caused by coal mine dust is a progressive disease and respiratory morbidity including ongoing fibrosis and functional impairment can occur after exposure ceases. To our knowledge, no contemporary studies have explicitly focused on post-exposure progression in the USA. Research on the post-exposure progression of former miners in the USA is warranted, given the recent increase of severe pneumoconiosis observed in active and former miners.

Pneumoconiosis in Silica-Exposed Coal Miners

Crystalline silica has been identified as an important factor in the resurgence of severe pneumoconiosis in Appalachian coal miners. Since 1980, the prevalence of r-type opacities (which are associated with silicosis lung pathology) has increased sixfold among underground coal miners in central Appalachia (PR 6.04, 95% CI 4.6–7.9), while remaining static in the rest of the nation. [47, 48] A 2016 case series described lung pathology consistent with accelerated silicosis and mixed dust pneumoconiosis among miners with rapidly progressive pneumoconiosis. [49] The radiographic findings strongly suggested, and the lung pathology findings documented, that these miners were exposed to silica and silicate minerals contained in respirable coal mine dust during their mining careers. In addition, studies that have examined specific jobs within the coal mining industry known to be associated with higher exposures to silica (e.g., underground roof bolters, surface drillers, and blasters) have shown that severe and rapidly progressive disease occurs more frequently among these workers when compared to coal miners in jobs associated with lower silica exposure. [18••, 23, 42, 43]

Case reports have identified the practice of slope mining, whereby workers use coal mining equipment to take extended cuts through rock to reach coal seams, as possibly associated with severe and rapidly progressive pneumoconiosis in underground miners. [18••, 24, 50] A recent report quoted a Kentucky miner reflecting on his experiences in thin-seam mining: “all the big seams of coal are gone, and they’re cuttin’ rock everywhere, and it’s just…the silica…It’s just unreal. You can’t breathe it.” [24] A 39-year-old miner who is completely disabled by PMF reflected on his experience cutting a slope through sandstone underground to reach a seam of coal: “It was pure rock dust. I had my respirators on and you’d actually have to remove it to help take a breath every once in a while because the dust packed so much around your filters you couldn’t get no air in.” [51] Although we do not know the generalizability of these experiences, it is clear that the many underground coal miners in Kentucky and Virginia with PMF have experienced substantial over-exposures to coal mine dust. [18••, 23, 24, 52]

Lung Transplantation for Coal Workers’ Pneumoconiosis

As the prevalence of pneumoconiosis continues to increase, studies have identified increasingly severe manifestations of the disease. A consequence of this is a marked increase in the frequency and rate of lung transplantation for pneumoconiosis in residents of central Appalachian states. With end-stage lung disease increasingly being observed in younger coal miners, it is likely that the pool of candidates requiring lung transplantation will grow. [53] There is no cure for CWP or silicosis, and patients might require lung transplantation as a medical intervention of last resort. A single transplant center study found that 30 patients with occupational lung disease, including 17 with CWP, who underwent lung transplantation between May 2005 and October 2016, had a median survival time of 6.6 years post-transplant. [54] However, studies based on data from the U. S. Organ Procurement and Transplantation Network (OPTN) show a median survival for patients with CWP ranging between 2.8 and 3.7 years. [55, 56]

During 1996–2014, 47 lung transplants were completed in patients with a probable CWP diagnosis (Fig. 4). [56] A follow-up report showed a continuing increase through 2017, with 15 additional lung transplants completed for patients with CWP or unspecified pneumoconiosis since 2014. Among these 62 patients undergoing lung transplantation during 1996–2017, mean patient age was 56.8 years, and 79% lived in Kentucky, Virginia, or West Virginia. [53] The average medical cost for a bilateral lung transplant in the USA is $1.2 million, and 65% of these lung transplants for probable CWP were paid for using public insurance funds. [53] An additional 27 patients with probable CWP were added to a waitlist for lung transplantation but had not undergone the procedure at the conclusion of follow-up. Eleven of these patients died prematurely while waiting for transplantation, and four were deemed too ill to undergo the surgery. Additional cases of CWP requiring transplant were likely underreported, because both analyses used data from the OPTN; misclassification is common in this registry, which was not designed to be used as a surveillance system. [57]

Because industry and occupation are not recorded in OPTN, and are often not recorded at the transplanting center, occupational attribution cannot always be clearly established. As such, manifestations of pneumoconiosis in coal miners that do not fit the classic definition, such as dust-related diffuse fibrosis, might be misdiagnosed or attributed to an unknown cause (such as idiopathic pulmonary fibrosis). However, dust-related diffuse fibrosis is far more commonly found among coal miners than idiopathic pulmonary fibrosis is found in the general population. [3, 4]

Mortality Studies

Exposure to coal mine dust is associated with increased mortality from malignant and non-malignant respiratory diseases. [58] Reported mortality for CWP in the general population has declined steadily since the 1980s. This trend is also observed in the Appalachian states that have seen increasing prevalence in recent years. One study found pneumoconiosis mortality rates decreased in West Virginia, Pennsylvania, Kentucky, and the USA during 2003–2013. [59] Although increasing prevalence of pneumoconiosis (including CWP) morbidity and declining mortality rates seem paradoxical, there are reasons why they might differ. Individuals can live for many years after a pneumoconiosis diagnosis, so recent cases may not contribute substantially to mortality statistics. In addition, mortality rates are calculated based on the entire population. The average number of coal miners in the USA has steadily declined since the early 1980s, from more than 250,000 in 1980 to 52,826 in 2018. [60] With fewer coal miners employed over time, the mortality rates have declined as well. Declining mortality rates could also be due to a low proportion of deaths from CWP being recorded as such on a death certificate. [61]

To estimate the burden of premature mortality within the declining population of coal miners, mean years of potential life lost (YPLL) is an important metric. In 2018, a study reported that during 1996–2016, mean CWP-attributable YPLL per decedent increased from 8.1 to 12.6 years. [61] YPLL per decedent is particularly sensitive to deaths at an early age. This increase is likely a result of the continued increase in the prevalence of severe manifestations of pneumoconiosis in coal miners.

Classification of Chest Radiographs by B Readers

In order to systematically identify and assess the presence and severity of abnormalities of pneumoconiosis associated with respirable dust exposure using chest radiography, physicians need to use a standardized scoring procedure including reference standards (standard radiographs) (Fig. 5). [62] The ILO International Classification of Radiographs of Pneumoconioses has met this need since 1950. [10] The ILO Classification System includes standard comparison films, and detailed descriptions of abnormalities and other radiographic features of importance to be noted during radiographic classification of pneumoconiosis. [10]

To establish a pool of physicians qualified to perform ILO classification of chest radiographs and reduce variability in how physicians classify chest radiographs of coal miners, NIOSH started the B Reader Program to train and certify physicians to use the guidelines for the use of the ILO classification system. [10, 63, 64] Certified B Readers are physicians who have successfully passed the certification examination, demonstrating competence with the ILO system. [63] This designation is important as numerous studies have identified differences in how B Readers and non-B Readers classify radiographs. Specifically, compared to B Readers, physicians who have not passed the certification examination tend to over-read for disease presence and severity. [64–68] B Readers are not only used in the CWHSP but also for screening other workforces (e.g., those exposed to silica, asbestos) and for other public health and medicolegal purposes. Given this and the importance of using B Readers to accurately identify disease, it is concerning that the number of those who are certified has decreased over time from nearly 400 B Readers in the mid-2000s to 165 B Readers today. [69] Increasing B Reader trainings and examination opportunities for US physicians is currently a major focus for NIOSH.

Because NIOSH has maintained a pool of experienced and highly competent readers over a long time period, data generated by B Readers can be reliably used to assess patterns of pneumoconiosis presentation over time. For example, the presence of predominantly upper lobe rounded opacities has long been viewed as the classic radiographic presentation of pneumoconiosis caused by coal mine dust, with irregular opacities and lower lobe predominant opacities viewed as uncommon. However, recent studies have challenged these views, showing that radiographic distribution of opacities in coal miners is not always upper lobe predominant. [4, 13] A study of 2476 underground US coal miners showed even distribution of opacities among the upper and lower lobes, with irregular opacities in 37.9%. [4] In the past, it may have been expected that severe manifestations of disease developed primarily in miners with a mining tenure of at least 25 years. However, a study of radiographs among coal miners participating in the CWHSP showed that 17% with severe disease progressed from normal radiographs to PMF in less than a decade. [70]

Other Respiratory Conditions Caused by Coal Mine Dust

As previously noted, coal mine dust is a complex mixture that can vary between mines and regions and can cause a spectrum of lung diseases. [4, 49, 71] Coal mine dust can cause radiographically apparent interstitial lung diseases including CWP, silicosis, mixed dust pneumoconiosis, and dust-related diffuse fibrosis, all of which are identified as pneumoconiosis by radiographic surveillance. Coal mine dust can also cause COPD (including chronic bronchitis and emphysema), which is not reliably detected by chest radiography and is best screened for by lung function testing. Exposure to coal mine dust is an independent risk factor for emphysema. [72] In addition, small airways disease can cause significant functional impairment and is an important part of the spectrum of disease caused by coal mine dust. [73] On average, progressively lower lung function is associated with increasing small opacity profusion for each spirometric measure, with the strongest effect for FEV1% predicted. [74] Thus, it has become increasingly clear that respirable coal mine dust contributes to a diverse spectrum of respiratory diseases not limited to classical, radiographically apparent pneumoconiosis.

Conclusions

This review highlights recent research on pneumoconiosis in US coal miners. Following identification of resurgent pneumoconiosis and PMF using radiographic surveillance data, numerous independent sources of coal miner health information have corroborated these trends, most notably in the central Appalachian region.

These troubling findings have been widely acknowledged by stakeholders outside of the world of occupational safety and health. [7, 30, 38, 75, 76] Amid reports of the rising prevalence of severe pneumoconiosis cases, MSHA released its final rule introducing more stringent protections against coal mine dust exposures, including a reduced PEL, in 2014. [7] The U.S. Government Accountability Office investigated the scientific basis for the reduced PEL, ultimately publishing two reports concluding that appropriate scientific evidence existed to support the rule. [75, 76] The NAS published its report discussing strategies to reduce exposure to respirable coal mine dust, describing current monitoring and sampling methods and providing recommendations for improvements. [30] Most recently, the U.S. Senate [38] directed NIOSH to report on barriers to participation in the CWHSP. A final report on this topic is forthcoming.

The surveillance data are compelling, but the human side to this continuing occupational disease is exemplified in stories from coal miners suffering from debilitating disease caused by their work. In 2013, a year-long Pulitzer Prize–winning investigation, *Breathless and Burdened*, led by Chris Hamby, gave a face to the statistics and detailed stories of miners affected by black lung, including some who had already passed away from the disease. [77]

More stories from central Appalachia have described miners and families whose lives had been adversely affected by coal mine dust–induced lung disease. Articles and interviews appeared on National Public Radio, [51, 78–80] the New York Times, [81] and the Guardian, [82] as well as on blogs and podcasts. [82–86] In January 2019, the issue was featured nationally on PBS Frontline, following a year-long investigation led by NPR's Howard Berkes. [87]

The increased scientific and media attention has precipitated extensive reforms to programs designed to prevent pneumoconiosis in coal miners and mitigate its negative health effects, including a 40% increase in funding for federally supported black lung clinics. Coal mining will remain an important industry in the USA for the foreseeable future. Currently, there are more than 47,000 working coal miners. [60] It is important that they work in settings that are compliant with dust exposure protections and have access as required to confidential health screening services. Thousands more former coal miners suffer from disabling respiratory disease caused by coal mine dust and are entitled to benefits to address health problems caused by their work. Pneumoconiosis in coal miners is preventable and should at this point be a disease of the past. The resurgence of pneumoconiosis in US coal miners provides a cautionary tale and underscores the critical importance of effective dust exposure protections coupled with vigorous health surveillance activities.

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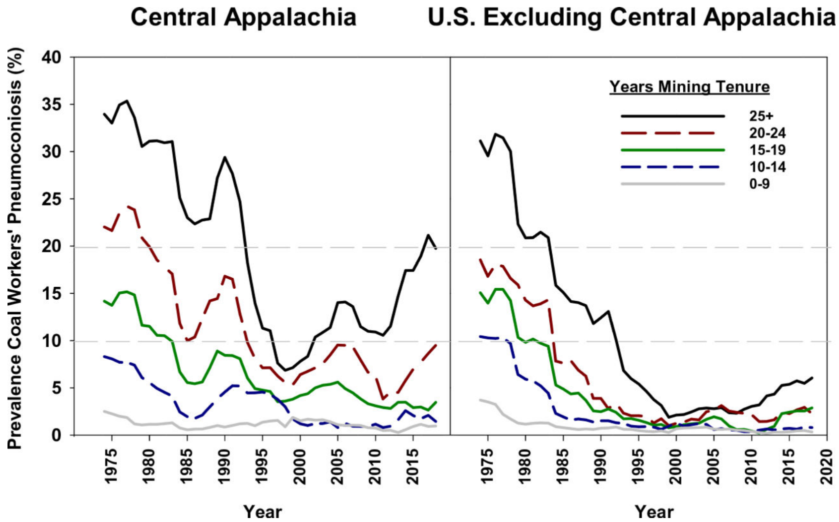

Fig. 1.

Prevalence of pneumoconiosis among working underground coal miners participating in the Coal Workers' Health Surveillance Program, in central Appalachia and the USA excluding central Appalachia, 1974–2018. Note: Central Appalachia includes Kentucky, Virginia, and West Virginia. Data are presented as the 5-year moving average percentage; surveillance is conducted on a 5-year national cycle

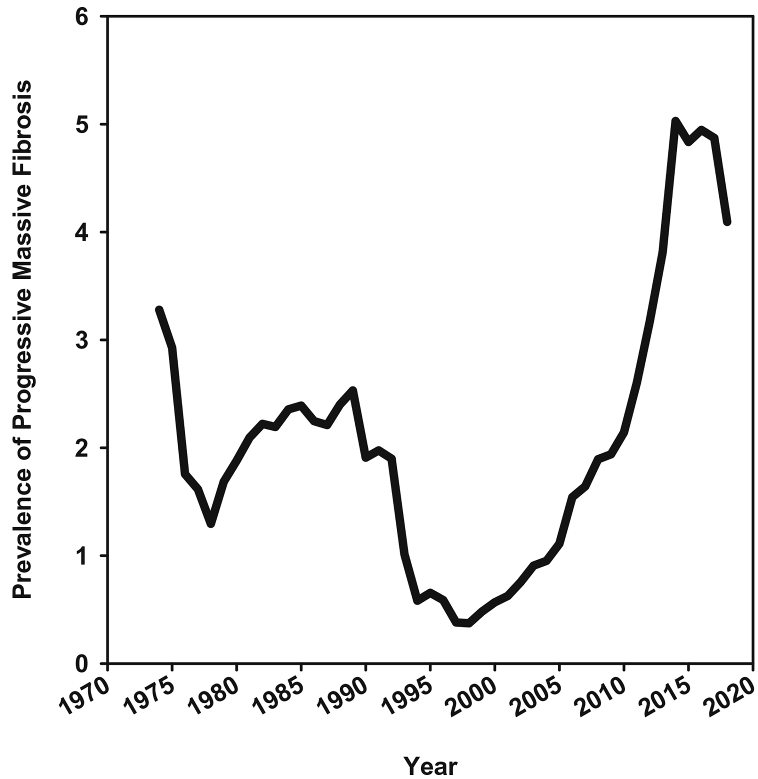

Fig. 2.
Prevalence of progressive massive fibrosis among working underground coal miners with 25 or more years of underground mining tenure participating in the Coal Workers' Health Surveillance Program in Kentucky, Virginia, and West Virginia, 1974–2018. Note: Data are presented as the 5-year moving average percentage; surveillance is conducted on a 5-year national cycle

Fig. 3.

Photograph taken by a miner in 2012 at a surface coal mine; it shows three miners enveloped in a dust cloud loading drill holes to blast overburden. Reprinted with permission from "Debilitating Lung Disease Among Surface Coal Miners With No Underground Mining Tenure," by C.N. Halldin, W.R. Reed, et al., 2015, J Occup Environ Med, 57 (1):62–67

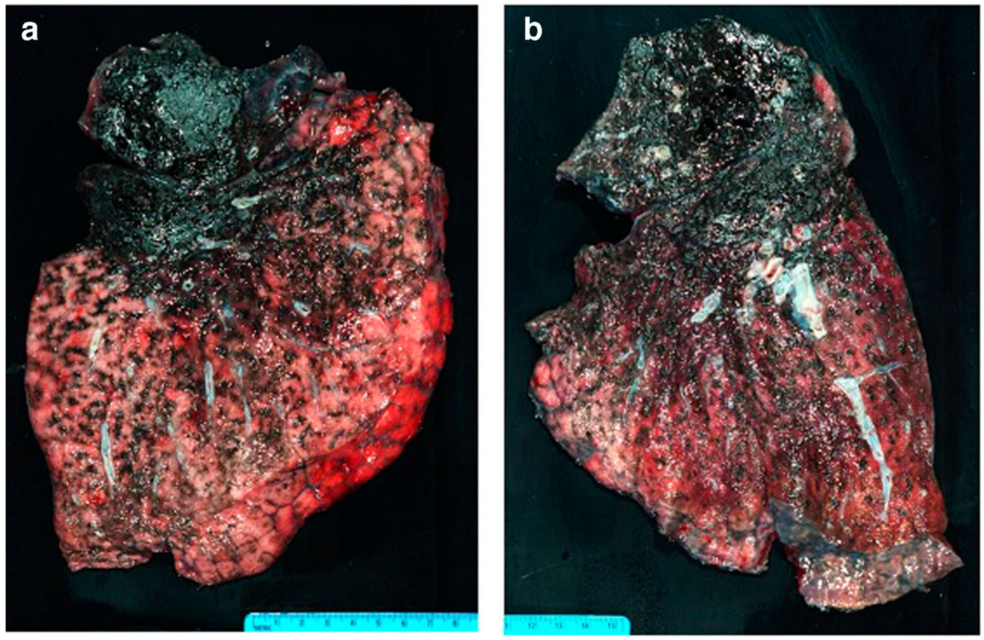

Fig. 4.
Explanted lungs of a male Northern West Virginia coal miner with progressive massive fibrosis who underwent bilateral transplant at age 60 years (Panel a is a photograph of the right explanted lung, Panel b the left lung). He was a life-long never smoker who began his mining career in 1973 at the age of 21. He had 35 total years of mining tenure with 28 years as a continuous miner operator. He exercised Part 90 transfer rights 4 years prior to leaving mining in 2008. The upper left lobe is replaced by progressive massive fibrosis (PMF). The pale nodular areas within the PMF, seen most clearly in the right lung, suggest a component of silicosis

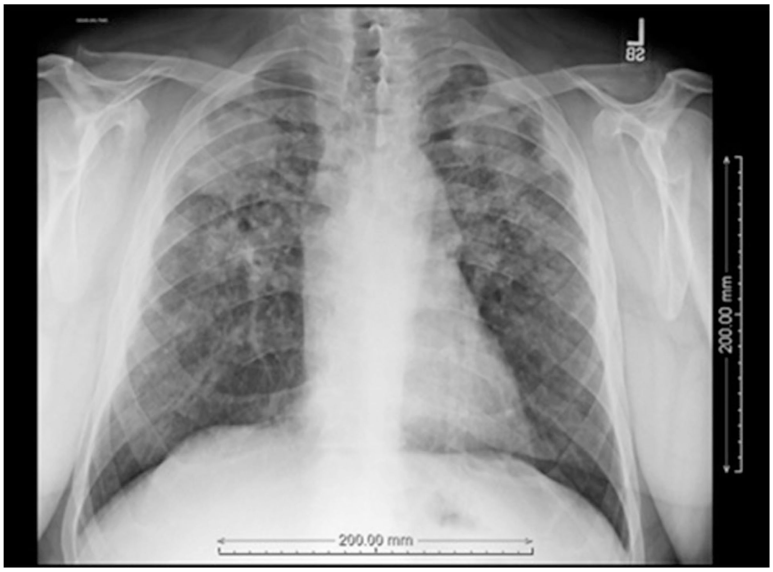

Fig. 5.
Chest radiograph image taken in 2016 of a 56-year-old male eastern Kentucky resident with 29 years of total mining tenure (including 11 years as a roof bolter). Image classified as category C large opacity, with 3/2 small opacity profusion, and primarily rounded opacities (q-type)