OEM Online First, published on April 13, 2017 as 10.1136/oemed-2016-104249

SHORT REPORT

Radiographic disease progression in contemporary US coal miners with progressive massive fibrosis

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Received 9 December 2016
Revised 17 February 2017
Accepted 19 March 2017

ABSTRACT

Introduction Among contemporary US coal miners, there has been an increase in the prevalence and severity of pneumoconiosis, including its advanced form progressive massive fibrosis (PMF). We examine radiographic progression in Coal Workers' Health Surveillance Program (CWHSP) participants.

Methods CWHSP participants with a final determination of PMF during 1 January 2000–1 October 2016 with at least one prior radiograph in the system were included. We characterised demographics, participation and progression patterns.

Results A total of 192 miners with a PMF determination contributed at least one additional radiograph (total count: 2–10). Mean age at first radiograph was 28.8 years, 162 (84%) worked in Kentucky, Virginia or West Virginia and 169 (88%) worked exclusively underground. A total of 163 (85%) miners had a normal initial radiograph. Mean time from most recent normal radiograph to one with a PMF determination was 20.7 years (range: 1–43) and 27 (17%) progressed to PMF in less than 10 years.

Discussion Dust exposure is the sole cause of this disease, and a substantial number of these miners progressed from normal to PMF in less than a decade. Participation in CWHSP is voluntary, and these findings are influenced by participation patterns, so for many miners it remains unclear how rapidly their disease progressed. The National Institute for Occupational Safety and Health recommends all working miners to participate in radiographic surveillance at 5-year intervals. Improved participation could allow more precise characterisation of the burden and characteristics of pneumoconiosis in US coal miners and provide an important early detection tool to prevent cases of severe disease.

What this paper adds

- Dust exposure is the sole cause of progressive massive fibrosis (PMF).
- Surveillance data from US Coal Workers' Health Surveillance Program suggest a substantial number of coal miners in this study progressed from normal to PMF in less than a decade.
- It is likely that some miners work for years with severe lung disease that went undetected by the surveillance programme until they participated close to or after retirement.
- The National Institute for Occupational Safety and Health recommends that all miners participate in spirometric and radiographic surveillance at 5-year intervals throughout their working career.

INTRODUCTION

Recent reports have demonstrated an increase in prevalence of severe pneumoconiosis including progressive massive fibrosis (PMF) in US coal miners during the last 15 years.[1] This has garnered widespread attention including a Pulitzer Prize-winning investigative journalism series, congressional hearings, federal rulemaking and, most recently, the report of a previously unidentified outbreak of PMF in eastern Kentucky coal miners.[2] Multiple independent data sources paint a consistent picture: among contemporary US coal workers, pneumoconiosis is more prevalent and more severe than it was a quarter century ago. In addition to the recent attention surrounding the outbreak of PMF in eastern Kentucky, scientific reports from the last decade have documented a regional resurgence of PMF,[1] rising frequency of lung transplants for pneumoconiosis,[3] increasing numbers of disability claims filed for state and federal black lung compensation, presence of severe disease in surface miners,[4] elevated rates of abnormal lung function in former miners,[5] increases in mean years of potential life lost among coal miners with pneumoconiosis, rapidly progressive disease[6] and advanced disease in relatively young miners.[7 8]

To our knowledge, since 2000, two studies have reported on disease progression in US coal workers with severe pneumoconiosis. The first study used data from 1996 to2002 and focused on geographical clustering of rapidly progressive cases.[6] The second study found that a subgroup of miners with serial radiographs (n=43) progressed from normal to PMF in a mean of 12.2 years.[7] We examine the radiographic progression patterns of pneumoconiotic opacities among recent participants (since 1 January 2000) of the national Coal Workers' Health Surveillance Program (CWHSP) with at least one radiographic classification of PMF.

METHODS

Data were derived from the National Institute for Occupational Safety and Health (NIOSH)-administered CWHSP. Radiographs for the pneumoconioses are classified by multiple NIOSH-approved physicians using the International Labour Office system.[9] Physicians classify small opacity profusion using a four-point major category scale (0, 1, 2 and 3), with category 1 or higher considered radiographic evidence of pneumoconiosis. Large

To cite: Laney AS, Blackley DJ, Halldin CN. *Occup Environ Med* Published Online First: [please include Day Month Year]. doi:10.1136/oemed-2016-104249

opacities (or PMF), defined as any opacity >1 cm, are classified as category A, B or C. All individuals with a final determination of PMF during 1 January 2000–1 October 2016, and with at least one prior radiograph in CWHSP, were included in this analysis. SAS V.9.3 was used to calculate descriptive statistics of participants, determine time intervals between radiographs, assess mean time of progression and identify patterns of CWHSP participation.

RESULTS

Among the 60 205 miners who participated in health surveillance during the study period, PMF was identified in 225 miners. Of these 225, the study group comprised 192 miners (85.3%) who had at least one additional radiograph available (range: 2–10), for a total of 757 available radiographs. All participants were men; 97.7% with information on race/ethnicity were white (172/176), and the mean age at first radiograph was 28.8 years (median 25; range 18–61). These miners worked in eight different states, with 32 (17%) working in more than one state during their career, and 162 (84.4%) working in the central Appalachian states of Kentucky, Virginia and West Virginia for at least some of their career. A majority of miners worked underground, with 169 (88.0%) working exclusively underground and 15 (7.8%) working in both underground and surface mines. Eight miners (4.2%) worked exclusively at surface mines.

Participation and progression patterns

A total of 163 (84.9%) miners had a normal initial CWHSP radiograph (defined as small opacity profusion major category 0 and the absence of large opacities). The mean time from the most recent normal radiograph to a radiograph with a determination of PMF was 20.7 years (median 20; range 1–43). Of these 163 miners, 27 (16.6%) progressed to PMF in less than 10 years, 57 (35.0%) progressed to PMF in 11–20 years and 79 (48.5%) miners progressed from normal to PMF in more than 20 years. The total number of radiographs contributed by a given miner correlated with earlier detection of PMF as demonstrated by mean time from normal to PMF (figure 1). For example, among miners with a normal initial radiograph who had two radiographs, the median time from normal to detection of PMF was 28 years (mean 25.6); this compares with 14 years (mean 15.2) in miners who contributed six or more radiographs. In addition, miners who start with a normal radiograph and contribute multiple radiographs throughout their careers tend to have increasing profusion of small opacities that are identified prior to identification of PMF. In addition to the 163 study miners whose initial programme radiograph was normal, 19 other miners had an initial radiograph that showed pneumoconiosis of category 1, 2 or 3 and progressed to PMF on later radiographs. For 10 other miners, the initial radiographic determination was PMF, and for these miners, participation showed a predominant pattern of additional radiographs tightly clustered in time.

Figure 1 presents radiographic determinations for the 192 miners, stratified by the number of radiographs contributed by the miner. Three broad participation patterns emerged: (1) a pre-employment, early career radiograph or cluster of radiographs classified as normal, with an end-career radiograph or cluster of radiographs classified as PMF and high profusion of small opacities; (2) multiple radiographs with advanced pneumoconiosis clustered together during late career; and (3) regular radiographs throughout a miner's career tenure.

Former miners

A total of 18 of these miners contributed a radiograph after they had ceased working. Mean time from normal to PMF in this group was 24.3 years (1–43 years). Of these 18 former miners, seven (38.9%) had two radiographs, 32 years apart on-average, likely indicative of CWHSP participation near the beginning and after (but not during) their mining careers.

DISCUSSION

We characterise radiographic progression of pneumoconiosis in 192 US coal miners who had a determination of PMF since 2000. Alarmingly, 27 (14.1%) rapidly progressed from normal to PMF in less than 10 years. This rate of progression is unusual, though it has been documented. 'Rapidly progressive coal workers' pneumoconiosis' has previously been defined as an increase in small opacity profusion subcategory >1 in a 5-year span and/or any case of PMF occurring in a miner younger than 70 years of age with less than 40 years of coal mining tenure.[10] It is important to note that all 192 cases in this report, and the additional 33 without multiple radiographs (for a total of 225), would fit within that definition of rapid progression.

Various factors are associated with progression to advanced disease in coal miners, including occupations at the coal face, roof bolting, small mine size, coal rank, mining tenure and others.[11] All of these represent risk factors for mass and composition of inhaled dust. Cochrane *et al*[12] put it succinctly in the 1960s by concluding: 'three factors—age, mining, and hard work—are likely to affect the progression rate' to PMF.

Among these miners, time to event (normal to PMF) and rate of progression of small opacity profusion category are likely influenced by participation patterns. For many miners, it remains unclear how rapidly their disease progressed. For example, one identified pattern involved early and late career participation with little to no mid-career participation. The estimates we report of time from a normal radiograph to PMF are inherently biased and underestimate the true rate of progression. It is likely that some miners in this study worked for years with severe lung disease that went undetected by our surveillance programme until they participated close to or after retirement. It is also now clear that there are a significant number of miners who have worked for years with severe lung impairment that have gone undetected by our surveillance programme altogether.[2]

The CWHSP is the only industry-wide federally mandated disease surveillance system in the USA. Miners are eligible to receive radiographs about every 5 years. If they are found to have any evidence of pneumoconiosis, the miner may exercise Part 90 transfer rights, where he or she may transfer to a less dusty part of the mine (if one exists) with protections for wages, shift and seniority. Although wage rates for Part 90 miners are legally protected, face miners often work many overtime hours, providing a considerable wage bonus. If miners with pneumoconiosis request transfer to a lower dust environment, earnings can be reduced if individuals are not offered similar overtime work and bonus pay. Even though these protections are set forth by federal law and participation in the programme is of no cost to the miner, recent participation rates for the CWHSP remain less than 50%. In addition, participation rates differ by mining region. Though the number of PMF cases is highest in central Appalachia, participation in radiographic surveillance by miners in that region is lower than in the rest of the UUSA.[2] Through informal focus groups with current and former miners, we have come to understand that many factors influence a miner's decision regarding whether to participate in voluntary medical

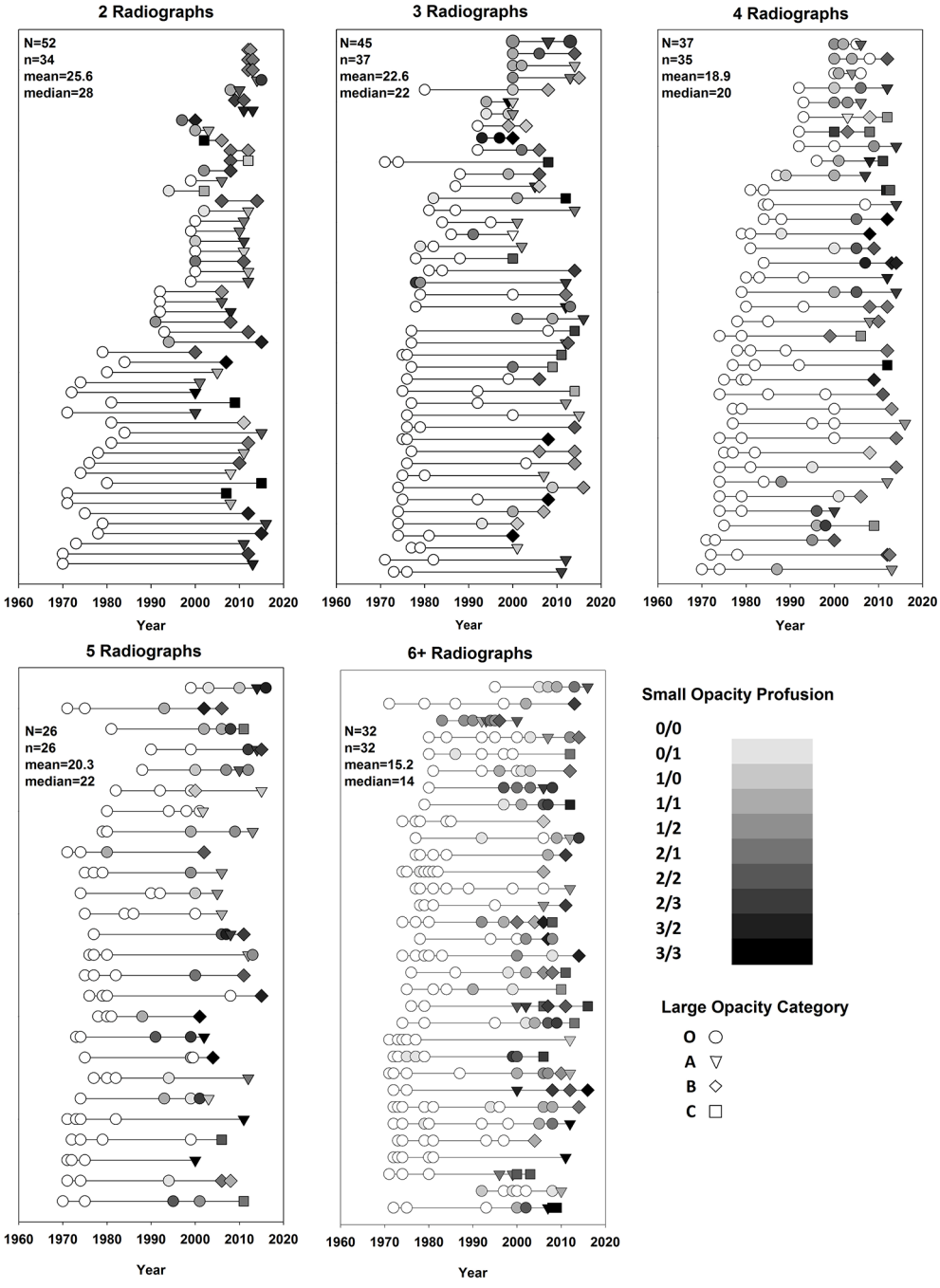

Figure 1 Serial radiographs of coal miners with PMF identified in the National Institute for Occupational Safety and Health-administered Coal Workers' Health Surveillance Program for the period 2000–2016. N is total number of radiographs, n is number of radiographs with an initial small opacity profusion category 0, mean and medians are time from major ILO category 0 to PMF in years. ILO, International Labour Office; PMF, progressive massive fibrosis.

surveillance. These include fear of reprisal at the worksite, state and federal disability compensation law and personal fear of knowing their own disease status.

Our findings demonstrate that pneumoconiosis in coal miners can rapidly progress to PMF. Coal mine dust exposure is the sole cause of PMF in these coal miners. A limitation of this study is that dust exposure data were unavailable at the individual level. Therefore, the most important metric driving progression is unaccounted for. However, early detection of respiratory impairment is the goal of the CWHSP and, to that end, periodic spirometry screening has been included as part of the programme. NIOSH recommends that all miners participate in spirometric and radiographic surveillance at 5-year intervals throughout their working career though a large proportion of miners do not. Current prevalence estimates of PMF among Appalachian working miners participating in the CWHSP have reached historic levels, and the prevalence of PMF may be substantially higher in the coal mining population than surveillance data have suggested.[2] To more accurately characterise the scope of pneumoconiosis in US coal miners and promote secondary prevention, a better understanding of barriers to CWHSP participation is needed and should include a focus on factors that impact differential participation by region. Only then can participation rates be improved, which would represent an important step in reducing the burden of this entirely preventable debilitating disease.

Contributors All listed authors contributed to the analysis and writing of this work.

Funding This study was funded by the National Institute for Occupational Safety and Health (NIOSH). Centers for Disease Control and NIOSH supported the salaries of the authors, and no other funding was obtained. This work was performed by Federal Government employees as part of their work; no non-governmental funding supported this work.

Disclaimer The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health (NIOSH). Mention of product names does not imply endorsement by NIOSH/Centers for Disease Control.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

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Occup Environ Med published online April 13, 2017

Notes