

Pneumoconiosis progression patterns in US coal miner participants of a job transfer programme designed to prevent progression of disease

Noemi B Hall , David J Blackley, Cara N Halldin, A Scott Laney 

Respiratory Health Division,
National Institute for
Occupational Safety and Health,
Morgantown, West Virginia,
USA

Correspondence to

Dr A Scott Laney, Respiratory
Health Division, National
Institute for Occupational Safety
and Health, Morgantown, WV
26505, USA; aol4@cdc.gov

Received 8 November 2019

Revised 22 January 2020

Accepted 26 February 2020

Published Online First

13 March 2020

ABSTRACT

Objectives Pneumoconiosis prevalence and severity among US coal miners has been increasing for the past 20 years. An examination of the current approaches to primary and secondary prevention efforts is warranted. One method of secondary prevention is the Mine Safety and Health Administration-administered part 90 option programme where US coal miners with radiographic evidence of pneumoconiosis can exercise their right to be placed in a less dusty area of the mine. This study focuses on characterising the progression of disease among US coal miners who participated in the National Institute for Occupational Safety and Health-administered Coal Workers' Health Surveillance Programme (CWHSP) and exercised their part 90 job transfer option.

Methods Chest radiograph classifications of working underground coal miners who exercised their part 90 job transfer option during 1 January 1986 to 21 November 2016 and participated in the CWHSP during 1 January 1981 to 19 March 2019 were analysed.

Results 513 miners exercised their part 90 option and participated in the CWHSP at least once during this time period. Of the 149 miners with ≥ 2 radiographs available, 48 (32%) showed progression after exercising part 90 and had more severe disease prior to exercising, compared with miners who did not progress (severity score of 2.8 vs 1.7, $p=0.0002$).

Conclusion The part 90 job transfer option programme is not routinely used as intended to prevent progression of pneumoconiosis among US coal miners. The one-third of miners who participated in part 90 and continued to progress, exercised their part 90 option at a later stage of disease compared with non-progressors.

INTRODUCTION

The prevalence and severity of pneumoconiosis in US coal miners has markedly increased in the last 20 years.^{1 2} Changes in the composition of the dust, including excessive exposure to crystalline silica, have been implicated in playing a role in the observed resurgence of disease and the increase in the most severe forms including progressive massive fibrosis (PMF).^{3–6} Federal standards, first enacted in 1969, established primary and secondary prevention programmes to protect underground coal miners from material respiratory impairment resulting from excessive exposure to coal mine dust.⁷ Given the increase in prevalence and severity of pneumoconiosis, thorough examination of the

Key messages

What is already known about this subject?

- The part 90 job transfer option programme has been in place for 50 years and miners are informed of this right when they participate in radiographic screening. Over 85% of working coal miners who have participated in screening and have radiographic findings of pneumoconiosis have not exercised their right to transfer to a lower dust environment.

What are the new findings?

- Of the less than 15% of coal miners who do exercise their part 90 job transfer option and continue to work, one-third have progression of their pneumoconiosis.

How might this impact on policy or clinical practice in the foreseeable future?

- The established primary and secondary prevention systems for early identification and cessation of progression are not achieving their intended objectives. New policies should be considered to prevent the ongoing epidemic of debilitating lung disease in US coal miners.

current approaches to primary and secondary prevention efforts are warranted.

Primary prevention efforts are meant to reduce the incidence of disease and include administrative and engineering controls such as ventilation plans and dust suppression or capture devices. Primary prevention activities are enforced by the Mine Safety and Health Administration (MSHA) and include review and approval of adequate mine ventilation plans and periodic compliance sampling for respirable coal mine dust and respirable quartz. Primary prevention of coal mine dust exposures was the focus of a recent and comprehensive National Academy of Sciences consensus study report.⁸ On 29 August 2019, MSHA published a Request for Information in the Federal Register soliciting comment from the public regarding primary prevention strategies for managing quartz exposure in mines including 'an examination of an appropriately reduced permissible exposure limit, potential new or developing technologies and/or technical and educational assistance'.⁹



© Author(s) (or their employer(s)) 2020. No commercial re-use. See rights and permissions. Published by BMJ.

To cite: Hall NB, Blackley DJ, Halldin CN, et al. *Occup Environ Med* 2020;**77**:402–406.

Secondary prevention efforts are designed to reduce severity of disease through early detection of pneumoconiosis and subsequent job reassignment to a less dusty working environment. This is accomplished through routine radiographic screening in the National Institute for Occupational Safety and Health (NIOSH)-administered Coal Workers' Health Surveillance Programme (CWHSP) and the MSHA-administered part 90 option programme where miners with radiographic evidence of pneumoconiosis can exercise their right to be placed in a less dusty area of the mine. Authorised under 30 Code of Federal Regulations (CFR) part 90, the programme provides a mechanism for miners to remain employed while preventing progression of pneumoconiosis through reductions in dust exposure.¹⁰

When permissible dust limits for coal mining were first established in 1969,⁷ the exposure-response data underpinning the standards suggested that no cases of pneumoconiosis as severe as small opacity major category 2 (using the International Labour Office (ILO) classification system) would develop among miners who worked 35 years exposed continuously to 2 mg/m³ of respirable coal mine dust. In addition, researchers predicted that the 2 mg/m³ standard would lead to the eradication of PMF.¹¹ In the intervening years, and with the accumulation of evidence of adverse health effects (including PMF) continuing to occur under the 1969 standard, NIOSH recommended in 1995 a reduction to 1 mg/m³.^{11,12} In 2014, MSHA reduced the permissible exposure limit to 1.5 mg/m³ and NIOSH added pulmonary function testing and symptom assessments to the medical monitoring of the CWHSP. In addition, the programme was expanded to include surface coal miners. Though enhancements to primary and secondary prevention programmes were made in 2014 through regulatory actions by MSHA and NIOSH,^{10,13,14} the effectiveness of these prevention programmes has been called into question.¹⁵

Though it is unlikely that this job transfer programme conveys meaningful benefit for those who do not use it, a formal assessment of part 90 has not previously been conducted among the minority of eligible miners who do exercise their rights. This analysis examines the efficacy of the secondary prevention efforts of early detection of pneumoconiosis and participation in a job transfer programme and assesses disease progression rates and patterns among miners who exercised their part 90 job transfer option during the period of 1 January 1986 to 21 November 2016.

METHODS

Linking data from NIOSH and MSHA, working underground coal miners who exercised their part 90 job transfer option during 1 January 1986 to 21 November 2016 and also participated in the CWHSP during 1 January 1981 to 19 March 2019 were identified and included for analysis. Demographic information, state of employment, part 90 exercise date and chest radiograph classification data were used.

Radiographs were classified by at least two NIOSH-certified B Readers according to the guidelines for the use of the ILO International Classification of Radiographs of Pneumoconioses and regulations found at 42 CFR 37. Eligibility for part 90 is based on an NIOSH final determination of small opacity profusion ILO category 1/0 or greater according to CWHSP procedures.¹⁶

Regions were identified based on the state where a miner worked at the time of the most recent CWHSP encounter, with regions defined as eastern (Maryland, Ohio, Pennsylvania, Tennessee), interior (Arkansas, Illinois, Indiana, Iowa, Louisiana, Mississippi, Oklahoma, Texas), western (Arizona, Alaska,

Colorado, Montana, New Mexico, North Dakota, Utah, Washington, Wyoming) and central Appalachian (Kentucky, Virginia, West Virginia).

For this analysis, each radiographic classification was assigned a severity score, based on a 13-point scale, ranging from a severity score of 0 (indicating no evidence of pneumoconiosis on radiograph, with profusion of -/0, 0/0 or 0/1) through all levels of small opacity profusion (severity scores of 1 through 9 for profusion scores of 1/0 through 3/+). For those radiographs where a large opacity was identified, severity scores of 10 through 12 were assigned for large opacity category A, B and C, respectively. This 13-level severity score was then used to calculate change in classifications over time, taking both profusion and large opacity category into account.

For those miners who had two or more radiographic classifications available including at least one post-part 90 exercise date, categories were assigned to reflect the change in severity score from the radiograph immediately preceding the part 90 exercise date to the final radiograph available. If the change between the severity scores is greater than 0, the miner is categorised as a progressor. If the change is 0, then the miner is categorised as stable, and if the change is less than 0, then the miner is categorised as a regressor. Miners who do not show evidence of progression over the time period, both stable and regressors, are grouped together as non-progressors.

Analysis of the available data, including descriptive statistics and t-tests, was conducted using SAS V.9.4.

RESULTS

Of the 122 032 unique miners who participated in the CWHSP during 1 January 1981 to 19 March 2019, 4077 miners had at least one radiographic classification indicating pneumoconiosis and of these, 513 (12.6%) miners exercised their part 90 job transfer option during 1 January 1986 to 21 November 2016.

The majority of miners who exercised their part 90 job transfer option were men (99.8%) and white non-Hispanic (94.6%) (table 1). The mean age at the part 90 exercise date was 50.9 years. Among the 308 (60.0%) miners working in central Appalachia after exercising their part 90 option, 183 worked in West Virginia, 58 in Kentucky and 67 in Virginia.

Among the 513 CWHSP participants who exercised their part 90 option, 158 had only 1 radiograph available, 205 had no

Table 1 Characteristics of part 90 coal miners participating in the CWHSP, 1 January 1981 to 29 March 2019

No of miners	513
Years of age at part 90 exercise date (mean±SD)	50.9±7.1
Male	510 (99.8%)
White non-Hispanic	442 (94.6%)
Region last worked	
Eastern	72 (14.0%)
Interior	40 (7.8%)
Western	93 (18.1%)
Central Appalachian	308 (60.0%)
Time in years between first pneumoconiosis classification and part 90 exercise date (mean±SD)*	2.54±4.1

Frequencies presented as no.(%), miner age in years and time intervals presented as mean±SD. Values were missing for some observations (2 date of birth, 2 sex, 46 race/ethnicity).

*n=354, calculated for those with ≥2 X-rays.

CWHSP, Coal Workers' Health Surveillance Programme.

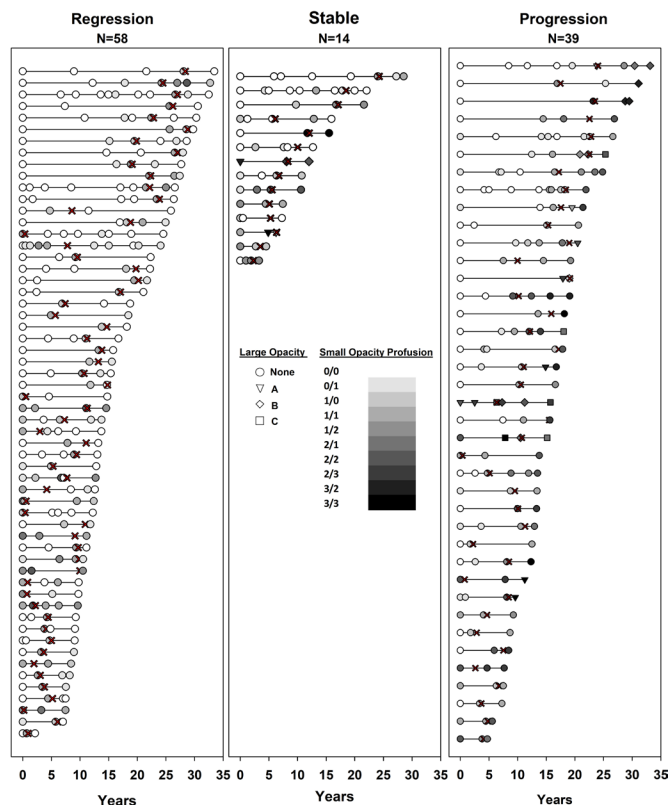


Figure 1 Radiographic Classifications for part 90 miners participating in the CWHSP with 3 or more radiographs (n=111), 1986–2016. Each timeline represents a single miner, with each radiograph as a distinct event on the timeline, and classifications represented as indicated in the figure legend (by profusion and presence of large opacity). Each red X indicates the date of part 90 exercise for that miner.

further radiographs available following the part 90 date of exercise and 1 was excluded as an outlier, having greater than 20 recorded radiographs. Of the remaining 149 miners who had two or more radiographs (range: 2–11) available, 101 miners were defined as non-progressors (79 regressors, 22 stable) and 48 were defined as progressors. The classification of each available radiograph for miners who exercised their part 90 option and also had three or more radiographs available in the CWHSP (n=111) is shown in figure 1.

The mean time between a miner's first CWHSP classification of pneumoconiosis and exercise of part 90 was 2.54 years for

the 354 miners with two or more radiographs, regardless of the availability of radiographs post-part 90 exercise date (table 1). For the 149 with two or more radiographs including at least one post-part 90 exercise date, the mean time was 1.98 years (range: 0.2–12.1 years) for non-progressors and 2.3 years (range: 0.1–13.1 years) for progressors (p=0.52, table 2).

For those who progressed, the absolute difference in severity score from the radiograph immediately preceding exercise date to the final available radiograph for a miner was 2.8, and for those who did not progress, the difference was 1.7 (p=0.0002, table 2). Among the 17 part 90 miners who had evidence of PMF by the time of their most recent radiograph in the present study, 12 (70.5%) failed to exercise their transfer right prior to reaching profusion category 2/1, and 9 miners already had evidence of PMF prior to exercising their part 90 job transfer option. For the 123 miners who exercised their rights prior to reaching category 2/1, 5 (4%) progressed to PMF during the study period.

DISCUSSION

Though the part 90 transfer option programme has been in place for 50 years and miners are informed of this right when they participate in radiographic screening, over 85% of working coal miners who have participated in screening and have radiographic findings of pneumoconiosis have not exercised their right to transfer to a lower dust environment. Among those who do, about one-third have progression of their pneumoconiosis as they continue to work after exercising their part 90 job transfer option. These findings highlight the importance of routine radiographic screening throughout a miner's working career to identify disease early when interventions, like job transfer, can be implemented to prevent progression to completely disabling disease.

In 1962, Cochrane wrote 'It is argued that the logical way to control the appearance of progressive massive fibrosis is to concentrate on preventing miners reaching category 2 of simple pneumoconiosis.'¹⁷ Our findings are consistent with that conclusion. However, it is important to note that the current study is limited to working miners. Postexposure progression of fibrosis has been documented and is common in severe pneumoconiosis.^{18–22} It is likely that miners who progressed in this study will continue to progress.

The presence of miners whose classifications show regression from the radiograph taken just before the part 90 exercise date to the final available radiograph within the study period (n=79) may reflect challenges of classifying low profusion. Compared with those who show progression, these miners have an initial

Table 2 Descriptive statistics for radiographic classifications and disease progression by progression status

	Progressors	Non-progressors	P value*
No of miners	48	101	
No of miners who exercised part 90 before 2/1 classification (%)	33 (68.8)	90 (89.1)	
Years of age at part 90 exercise date	49.6±6.9	49.1±6.8	0.67
Time in years from radiograph preceding part 90 exercise date to final radiograph	6.1±3.9	6.3±4.3	0.83
Severity at first classification of pneumoconiosis	3.1±2.6	2.3±1.8	0.02
Severity at radiograph preceding part 90 exercise date	3.5±3.1	2.4±2.1	0.01
Severity at final radiograph	6.3±3.6	1.05±2.3	<0.0001
Change in severity†	2.8±2.3	1.7±0.7	0.0002

Miner age, time intervals and severity scores presented as mean±SD. Severity is based on a 13-point scale, ranging from a severity score of 0 (no evidence of pneumoconiosis) through all levels of small opacity profusion (severity scores of 1 through 9 for profusion scores of 1/0 through 3/+), with severity scores of 10 through 12 assigned for large opacity category A, B and C.

*Pooled t-test used for equal variances, Satterthwaite used for unequal variance.

†Excludes those who remained stable (no change) from radiograph preceding part 90 exercise date to final radiograph.

radiographic classification of pneumoconiosis at a lower severity (2.3 for regressors vs 3.1 for progressors, $p=0.02$) and their absolute change in severity is smaller (1.7 for regressors vs 2.8 for progressors, $p=0.0002$). The apparent changes in classification may also be due to the effect of multiple readers, as previously described.²³ However, given the progressive nature of this fibrotic disease, it is likely that miners identified as non-progressors may go on to progress if followed into the future. Therefore, the proportion of miners we identified as having progressive disease in this study likely underestimates the total progression events and disease burden that will ultimately occur in this cohort.

A limitation that impedes our ability to monitor lifetime progression is that radiographic surveillance is currently limited to actively working miners. Consideration should be given to providing ongoing radiographic surveillance to long tenured miners postemployment as postexposure progression can occur and has implications for appropriate clinical management and disability compensation. It is likely that both lack of participation in radiographic screening and postexposure progression contribute to the discrepancy observed between the number of working miners with radiographic evidence of pneumoconiosis and the number of retired miners awarded total pulmonary disability benefits. For example, for the period 2006–2018, the US Department of Labor awarded benefits to 10019 retired miners based on total pulmonary disability arising from coal mining employment.²⁴ This was sixfold higher than those offered transfer rights in the same period (1674).

Overall disease severity at first eligibility was higher among progressors indicating disease was not identified early in some miners. Of the 149 miners with two or more radiographs, 31 (21%) waited to exercise their part 90 option until multiple radiographs showed evidence of pneumoconiosis. In sum, progression was associated with identifying disease in individuals later in the disease course and delays in exercising the part 90 option after eligibility.

The focus of this investigation was among US underground coal miners predominantly in the Central Appalachian bituminous coal fields. The exposure experience of this group of workers may not be representative of the exposures faced by miners in other countries. In addition, the systems in place for medical monitoring and reductions in exposure for miners with radiographic evidence of pneumoconiosis differs in other coal-producing nations.²⁵ However, the underlying principle of early identification of disease and subsequent exposure reduction is a prudent course of action wherever coal is mined. One factor that influences the effectiveness of these programmes in the USA is the voluntary nature of these systems.

Participation patterns

Participation in both radiographic screening and the part 90 job transfer option programme is voluntary and influences the ability to identify disease early and make timely interventions to reduce exposure. A clear limitation in fully understanding the natural history of progression of pneumoconiosis in contemporary coal miners is the lack of comprehensive exposure and clinical data. In the present study, of the 513 miners who exercised part 90 and participated in CWHSP, 158 had only one radiograph available and 205 had no further radiographs available following the part 90 date of exercise.

NIOSH encourages all coal miners to take advantage of the medical screening offered at no charge to themselves at routine intervals throughout their working careers. NIOSH conducts

outreach to make miners aware of when and where they can get their X-ray, spirometry and respiratory health assessments. Efforts to increase overall participation in the CWHSP have been enhanced through mobile screening efforts at or near mine sites, a variety of media campaigns in the US coal fields and through social media. Overall population participation has fluctuated between 20% and 40% in recent years. Many miners participate in the CWHSP early and/or late in their working careers but do not participate in the middle of their careers.²⁶ However, at the individual level, the importance of getting screened early and at regular intervals throughout a working career is the key to early detection.

We have previously reported that participation in the part 90 option programme is low (14.4% of eligible miners exercise their job transfer option) and that miners in Central Appalachia are even less likely to exercise the option (13.1% vs 17.3% in other states).²⁷ This alone demonstrates that this element of secondary prevention is not living up to its intended purpose. The reasons miners do not exercise their part 90 job transfer option are numerous and complex but privacy concerns and perceived fear of job loss have been noted.²⁸ To specifically address those concerns, MSHA promulgated rulemaking in 1980 to address low participation in the part 90 programme by providing additional protections related to job security, working hours, wages and work assignments. In the context of the 1980 part 90 rule update, mandatory transfer of miners with evidence of pneumoconiosis was considered as one mechanism to eliminate poor participation in the programme. MSHA ultimately excluded requirements for mandatory transfer of miners and in concluding the preamble to the proposed rule stated 'MSHA will monitor participation rates over the next 3 years, and if the number of miners exercising the part 90 option does not substantially increase, MSHA will reconsider the appropriateness of a mandatory transfer programme'. As noted by Spieler in a 1989 West Virginia Law Review, 'this was never done'.²⁹ Participation rates over time have remained relatively unchanged since the programme's inception.

This study highlights two primary findings. First, when effectively used to its potential, the systems in place for early identification of pneumoconiosis and enhanced protections from ongoing exposure appear to work as intended. Early identification of pneumoconiosis and reductions in or elimination of ongoing exposure provide protection against the most severe forms of the disease confirming previous research and long-held beliefs with regard to the natural history of dust-induced fibrotic lung disease. Second, the system is rarely effectively used to its potential. In an evaluation that was conducted over three decades ago Spieler reduced the issue to its essence, 'Does the programme accomplish its public health purpose?'^{28 29} Though the part 90 job transfer option programme has been in place for 50 years and miners are broadly aware that it is available to them, over 85% of working coal miners who have participated in screening and have radiographic findings of pneumoconiosis do not exercise their right to transfer to a lower dust environment. Among those who do, one-third have progression of their pneumoconiosis even after exercising their part 90 option.

Contributors NBH: analysed and interpreted the data, led writing of the article and takes responsibility for its content. DJB and CNH: assisted with interpreting data and writing the article. ASL: conceptualised and designed the study and helped with data interpretation and writing.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

ORCID iDs

Noemi B Hall <http://orcid.org/0000-0002-6710-2015>

A Scott Laney <http://orcid.org/0000-0002-3036-8960>

REFERENCES

- 1 Arnold C. A scourge returns: black lung in Appalachia. *Environ Health Perspect* 2016;124:A13–18.
- 2 Hall NB, Blackley DJ, Halldin CN, *et al.* Current review of pneumoconiosis among US coal miners. *Curr Environ Health Rep* 2019;6:137–47.
- 3 Blackley DJ, Crum JB, Halldin CN, *et al.* Resurgence of Progressive Massive Fibrosis in Coal Miners - Eastern Kentucky, 2016. *MMWR Morb Mortal Wkly Rep* 2016;65:1385–9.
- 4 Blackley DJ, Reynolds LE, Short C, *et al.* Progressive massive fibrosis in coal miners from 3 clinics in Virginia. *JAMA* 2018;319:500–1.
- 5 Hall NB, Blackley DJ, Halldin CN, *et al.* Continued increase in prevalence of R-type opacities among underground coal miners in the USA. *Occup Environ Med* 2019;76:479–81.
- 6 Doney BC, Blackley D, Hale JM, *et al.* Respirable coal mine dust in underground mines, United States, 1982–2017. *Am J Ind Med* 2019;62:478–85.
- 7 Federal Coal Mine Health and Safety Act of 1969 *Pub. L. No. 91-173, S. 2917* 1969.
- 8 National Academies of Sciences E, and Medicine; Health and Medicine Division; Division on Earth and Life Studies; Board on Health Sciences Policy; Board on Environmental Studies and Toxicology; Board on Earth Sciences and Resources; Committee on the Study of the Control of Respirable Coal Mine Dust Exposure in Underground Mines. *Monitoring and Sampling Approaches to Assess Underground Coal Mine Dust Exposures*. National Academies Press (US: Appendix C, Open-Session Meeting Agendas., 2018.
- 9 Mine Safety and Health Administration DoL. *Respirable crystalline silica, federal register*. National Archives, United States Government, 2019: 45452–6.
- 10 Department of Labor. Lowering Miners' Exposure to Respirable Coal Mine Dust, Including Continuous Personal Dust Monitors; Final Rule. In: *Department of Labor (ed.) 30 CFR 70, 71, 72*. Washington, DC, 2014.
- 11 National Institute for Occupational Safety and Health. A review of information published since 1995 on coal mine dust exposures and associated health outcomes. In: *Division of respiratory disease studies*. Morgantown, 2010.
- 12 Criteria for a recommended standard, occupational exposure to respirable coal mine dust, Cincinnati: NIOSH Publications Dissemination, 1995;DHSS (NIOSH) Publication No. 95-106. 13 U.S. Code of Federal Regulations 42. Chapter I. Part 37.
- 14 Reynolds LE, Wolfe AL, Clark KA, *et al.* Strengthening the coal workers' health surveillance program. *J Occup Environ Med* 2017;59:e71.
- 15 Congressional Record-Senate. Fiscal year 2019 federal budget, Amendment No. 3763, page S5902 2018.
- 16 Centers for Disease Control and Prevention (CDC). Pneumoconiosis prevalence among working coal miners examined in federal chest radiograph surveillance programs--United States, 1996–2002. *MMWR Morb Mortal Wkly Rep* 2003;52:336–40.
- 17 Cochrane AL. The attack rate of progressive massive fibrosis. *Br J Ind Med* 1962;19:52–64.
- 18 Maclaren WM, Soutar CA. Progressive massive fibrosis and simple pneumoconiosis in ex-miners. *Br J Ind Med* 1985;42:734–40.
- 19 Kimura K, Ohtsuka Y, Kaji H, *et al.* Progression of pneumoconiosis in coal miners after cessation of dust exposure: a longitudinal study based on periodic chest X-ray examinations in Hokkaido, Japan. *Intern Med* 2010;49:1949–56.
- 20 Coni NK. Apparent onset of coal-workers' pneumoconiosis after leaving the mines. *Br J Ind Med* 1967;24:243–6.
- 21 Stewart A. Pneumoconiosis of coal-miners; a study of the disease after exposure to dust has ceased. *Br J Ind Med* 1948;5:120–40.
- 22 Lee JS, Shin JH, Lee KM, *et al.* Serum levels of TGF- β 1 and MCP-1 as biomarkers for progressive coal workers' pneumoconiosis in retired coal workers: a three-year follow-up study. *Ind Health* 2014;52:129–36.
- 23 Halldin CN, Blackley DJ, Petsonk EL, *et al.* Pneumoconioses radiographs in a large population of U.S. coal workers: variability in a reader and B reader classifications by using the International labour office classification. *Radiology* 2017;284:870–6.
- 24 Department of Labor Office of Workers' Compensation Programs Division of Coal Mine Workers' Compensation. Black lung PDO claim decisions at the district director level FY 2006–2019 2020.
- 25 Wagner GR. *Screening and surveillance of workers exposed to mineral dust*. Geneva: WHO, 1996.
- 26 Laney AS, Blackley DJ, Halldin CN. Radiographic disease progression in contemporary us coal miners with progressive massive fibrosis. *Occup Environ Med* 2017;74:517–20.
- 27 Reynolds L, Halldin CN, Laney AS, *et al.* Coal miner participation in a job transfer program designed to prevent progression of pneumoconiosis, United States, 1986–2016. *Arch Environ Occup Health* 2018;73:344–6.
- 28 Shriver TE, Bodenhamer A. The enduring legacy of black lung: environmental health and contested illness in Appalachia. *Sociol Health Illn* 2018;40:1361–75.
- 29 Spieler EA. Can coal miners escape black lung? an analysis of the coal miner job transfer program and its implications for occupational medical removal protection programs. *W. Va. L. Rev* 1989;91.
- 30 Wagner GR, Spieler E, NIOSH D, ed. *Is the US coal miner chest X-ray surveillance program succeeding in controlling lung disease?* Pittsburgh, PA, 1990: 803–6.