

BMJ Open Radiographic features of importance in the National Institute for Occupational Safety and Health-administered Coal Workers' Health Surveillance Program: characterising the use of the 'other symbols'

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ABSTRACT

Objective The National Institute for Occupational Safety and Health-administered Coal Workers' Health Surveillance Program (CWHSP) provides radiographic pneumoconiosis screening for US coal miners. Radiographs are classified by readers according to International Labour Office criteria. In addition to pneumoconiotic parenchymal and pleural lung abnormalities, readers document radiographic features of importance (other symbols). Other symbols are not meant to imply a diagnosis or interpretation but are relevant as they provide information beyond a pneumoconiosis classification for features related to dust exposure and other aetiologies. Our objective was to summarise other symbol data from 48 years of CWHSP participants.

Methods Chest radiograph classifications obtained from CWHSP participants between July 1968 and July 2016 were analysed. Any 'other symbol' indication from any of the readings were counted. Frequencies were tabulated by individual reader and those identified by any reader.

Results Of the 469 922 radiographs included in this study, nearly 15% had at least one reader identify a radiographic feature of importance. The most commonly identified other symbol was cancer (excluding mesothelioma) (6.83%), followed by emphysema (1.68%). Some features were rarely identified over the 48 years of data collection such as rheumatoid pneumoconiosis (n=46), pneumothorax (n=32), mesothelioma (n=12) and rounded atelectasis (n=4).

Conclusions This is the largest study to date describing radiographic features of importance as part of routine chest radiographic surveillance. While these symbols are not diagnostic they can be used to describe features associated with dust exposure. One of the most commonly identified radiographic features in our population is emphysema which is associated with respirable dust exposure. These results can be compared with other dust exposed populations.

Strengths and limitations of this study

- This is the largest study to date describing radiographic features of importance as part of routine chest radiographic surveillance.
- Results from this study can be used when evaluating radiographic features of other dust exposed populations.
- While not unexpected, inter-reader agreement was generally poor with the highest agreement being for cancer which might be expected given the population prevalence and gravity of the condition.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) administers the Coal Workers' Health Surveillance Program (CWHSP) providing radiographic pneumoconiosis screening for US coal miners. According to the Federal Mine Safety and Health Act, radiographs are classified by readers according to International Labour Office (ILO) International Classification of Radiographs of Pneumoconioses.¹ In addition to pneumoconiotic parenchymal and pleural lung abnormalities, readers document other radiographic findings under the 'other symbols' section of Chest Radiograph Classification form. Notation of other symbols, if features exist, is an obligatory requisite of a complete ILO classification. Other symbols are not meant to imply a diagnosis or interpretation but are relevant as they provide further information outside of a pneumoconiosis classification for suspected features related to dust exposure and other aetiologies.

In 1990, roughly 8 and ½ years of data from the CWHSP were summarised with regard

to 'other symbols' indicated during the first and second ILO classification of radiographs.² Abnormal cardiac size or shape was most often identified followed by emphysema. Investigators demonstrated poor agreement between readers with respect to other symbols indicated during the ILO classification. Another study reviewed other symbols indicated during 10 years of the US Navy's Asbestos Medical Surveillance Program and found pleural thickening (2.35%) and cardiac size or shape (1.36%) to be the most commonly reported radiographic features.³ In this study, we sought to summarise other symbol data from 48 years of CWHSP participants.

METHODS

Chest radiograph ILO classifications obtained from CWHSP participants between July 1968 and July 2016 were analysed for any indication of the 28 possible 'other symbols'. Chest radiographs are classified by at least two (and up to five) physicians who have been trained or have demonstrated the ability to use the ILO pneumoconiosis classification system through the B Reader Certification Program administered by NIOSH.^{4,5} Physicians can become A Readers by attending a NIOSH-authorized course on the ILO classification system or by submitting examples of classifications to NIOSH for review. NIOSH B Reader certification requires demonstrating ongoing proficiency in the ILO classification system by passing a 6 hour examination and subsequent recertification examinations every 4 years thereafter.^{4,6} Prior to the CWHSP transition to digital radiography in 2012, the first ILO classification was usually completed by an A Reader at the local facility where the radiograph was obtained. Subsequent classifications were provided by NIOSH B Readers. Following 2012, new regulations required all classifications of digital chest images to be performed by B Readers.⁷ Therefore in this study, first readings are primarily from A Readers as they have provided the first readings for a majority of the programme's tenure. Second and subsequent readings have been done exclusively by B Readers.

SAS V.9.3 was used to tabulate the frequency of radiographic features indicated by other symbols, recorded by first reader only, second reader only, both the first and second reader and by any of up to five readers.

RESULTS

A total of 469 922 radiographs with a valid ILO classification were evaluated for the presences of any 'other symbol' classification; at least one reader indicated the presence of a radiographic feature of importance in 68 483 (14%) radiographs. For the 469 922 radiographs that were classified during the study period, the first reading was completed by an A Reader for 68.9% of radiographs (n=323 966), with the remaining first readings (n=145 956) being conducted by B Readers. All second and subsequent classifications were completed by

B Readers only. A Readers performing the first reading identified at least one 'other symbol' among 33 402 radiographs. B Readers who performed the first reading identified at least one 'other symbol' among 12 105 radiographs.

'Cancer of the lung or pleura' was the most commonly identified feature (46.9% of all radiographic features) identified in nearly 7% of the CWHSP radiographs (table 1). Emphysema was the second most commonly identified feature (11.5% of all radiographic features) identified in 1.7% of CWHSP radiographs. The least often indicated symbols during classification were rheumatoid pneumoconiosis, pneumothorax, mesothelioma and rounded atelectasis, together accounting for less than 100 identified instances in the CWHSP.

Agreement between first and second reader, where both the first and second reader identified the feature, was poor ranging from 0% to 27.9% agreement depending on the other symbol indicated and 16.3% overall. Agreement was highest for cancer of lung or pleura (27.9%) and calcified non-pneumoconiotic nodules or nodes (25.3%). Aside from the most uncommonly identified features, agreement was the poorest for the identification of honeycomb lung (1.9%).

DISCUSSION

The mandate of the CWHSP is to report on the respiratory health of US coal miners. This information is an important complement to the prevalence data that NIOSH regularly reports and are routinely used to assess prevalence and severity of coal workers' pneumoconiosis. In fact, NIOSH has made summary data publicly available through the CWHSP data query system.⁸ However, information on radiographic features of importance is not available and the only description of other symbols in the CWHSP was produced using 8 and ½ years of data from the 1980s. Because indication of other symbols (if they are present) are a requisite of an ILO classification, it is important to examine and report these findings. Additionally information on these radiographic features may be used in statistical analyses to help explain variation between readers in their classification of the same radiograph.

This is the largest study to date describing radiographic features of importance as part of routine chest radiographic surveillance. While these symbols are not meant for diagnostic purposes, they can be used to describe radiographic features associated with dust exposure and/or prompt clinical intervention in the case of features like cancer or tuberculosis. Emphysema, which is associated with respirable dust exposure, was one of the most commonly indicated symbols in our population. One of the least often indicated symbols was mesothelioma. As previously observed, inter-reader agreement was generally poor with the highest agreement being for cancer which might be expected given the population prevalence and gravity of the condition. Readers may be more

**Table 1** Frequency of 'other symbol' features of importance reported by first reader only, by second reader only, by both first and second reader, and by any reader* for 469922 chest radiographs taken in the Coal Workers' Health Surveillance Program between July 1968 and July 2016

Symbol	Description	First reader only	Second reader only	Both first and second reader	Any reader*	Total† (%)	Features indicated‡ (%)
ca	Cancer of lung or pleura	14 353	8502	8851	32 096	6.830	46.87
em	Definite emphysema	3769	3227	528	7879	1.677	11.51
co	Abnormality of cardiac size or shape	2727	3386	628	7166	1.525	10.46
hi	Enlargement of hilar or mediastinal lymph nodes	2411	2516	162	5491	1.168	8.02
cg	Calcified non-pneumoconiotic nodules (eg, granuloma) or nodes	2175	1554	1265	5112	1.088	7.46
kl	Septal (kerley) lines	3320	865	85	4520	0.962	6.60
cn	Calcification in small pneumoconiotic opacities	3393	900	85	4512	0.960	6.59
ax	Coalescence of small pneumoconiotic opacities	1786	1354	516	4335	0.922	6.33
bu	Bulla(e)	1475	1834	407	4308	0.917	6.29
fr	Fractured ribs	710	1395	585	2801	0.596	4.09
pi	Pleural thickening in interlobar fissure or mediastinum	1462	941	143	2725	0.580	3.98
cp	Cor pulmonale	932	772	217	2070	0.440	3.02
aa	Atherosclerotic aorta	572	734	172	1557	0.331	2.27
tb	Tuberculosis	353	727	63	1293	0.275	1.89
pa	Plate atelectasis	524	453	127	1142	0.243	1.67
di	Marked distortion of intrathoracic organs	403	278	80	852	0.181	1.24
ho	Honeycomb lung	118	86	4	589	0.125	0.86
es	Eggshell calcification of hilar or mediastinal lymph nodes	313	108	17	459	0.098	0.67
pb	Parenchymal bands	174	231	15	454	0.097	0.66
at	Significant apical pleural thickening	251	150	17	443	0.094	0.65
ef	Effusion	92	212	32	360	0.077	0.53
ih	Ill-defined heart outline	116	138	6	275	0.059	0.40
id	Ill-defined diaphragm outline	85	146	7	260	0.055	0.38
cv	Cavity	72	52	2	144	0.031	0.21
rp	Rheumatoid pneumoconiosis	9	21	0	46	0.010	0.07
px	Pneumothorax	9	15	2	32	0.007	0.05
me	Mesothelioma	1	8	1	12	0.003	0.02
ra	Rounded atelectasis	2	2	0	4	0.001	0.01
Total radiographs with at least one feature of importance indicated					68 483	14.56	100
Total Radiographs					469 922		

*Radiographs were read by up to five readers.

†Percentage calculated by dividing values in the 'Any reader' column by the total number of radiographs in this study (n=469922).

‡Percentage calculated by dividing values in 'Any reader' column by the total number of radiographs with at least one feature indicated (n=68483).

likely to indicate possible evidence to draw attention for immediate notification and primary care follow-up. First readings in this study were primarily conducted by A Readers as they have provided the first readings for a majority of the programme's tenure, whereas second readings were all done by B Readers. The poor inter-reader agreement observed in this study was not surprising as we recently demonstrated minimal agreement between A and B Readers with respect to film quality, presence of pneumoconiosis, small opacity profusion, and identification of pleural disease.⁹

When comparing to our findings, a report from the US Navy's Asbestos Medical Surveillance Program found similar prevalences of cardiac size/shape abnormalities (1.36% vs 1.53%) and tuberculosis (0.27% vs 0.28%) and a higher prevalence of fractured ribs (1.24% vs 0.60%). Interestingly they found much lower prevalences of cancer (0.56% vs 6.83%) and emphysema (0.74% vs 1.68%), both of which are associated with tobacco smoke and dust exposure, however, neither exposure was assessed in the Navy's report and we are not able to quantify either exposure in our programme.

US coal workers are not the only population of dust-exposed workers for whom ILO radiographic classifications are performed. Though coal mining is a unique industry with specific exposure hazards, these results, using five decades of data, can potentially be used as an approximate baseline if investigators researching other dust-exposed populations (silica, cotton, asbestos, etc) have concerns regarding the prevalence of any of the other symbols in their population.

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Contributors CNH planned, analysed and interpreted the data and led writing the manuscript. JMH assisted with analysis and interpretation of the data. DJB and ASL assisted with interpreting data and writing the manuscript.

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