Radiology

ORIGINAL RESEARCH ■ THORACIC IMAGING

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[1]

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Purpose: To assess the level of concordance between chest radiographic classifications of A and B Readers in a national surveillance program offered to U.S. coal miners over an approximate 36-year period.

Materials and Methods: The National Institute for Occupational Safety and Health (NIOSH) Coal Workers' Health Surveillance Program (CWHSP) is a surveillance program with nonresearch designation and is exempt from Human Subjects Review Board approval (11-DRDS-NR03). Thirty-six years of data (1979–2015) from the CWHSP were analyzed, which included all conventional screen-film radiographs with a classification by at least one A Reader and one B Reader. Agreement was assessed by using κ statistics; prevalence ratios were used to describe differences between A and B Reader determinations of image technical quality, small opacity profusion, and presence of large opacities and pleural abnormalities.

Results: The analysis included 79 185 matched A and B Reader chest radiograph classifications. A majority of both A and B Readers were radiologists (74.2% [213 of 287] vs 64.7% [22 of 34]; $P = .04$). A and B Readers had minimal agreement on technical image quality (κ = 0.0796; 95% confidence interval [CI]: 0.07, 0.08) and the distribution of small opacity profusion (subcategory κ, 0.2352; 95% CI: 0.22, 0.25). A Readers classified more images as "good" quality (prevalence ratio, 1.38; 95% CI: 1.35, 1.41) and identified more pneumoconiosis (prevalence ratio, 1.22; 95% CI: 1.20, 1.23).

Conclusion: A Readers classified substantially more radiographs with evidence of pneumoconiosis and classified higher small opacity profusion compared with B Readers. These observations reinforce the importance of multiple classifications by readers who have demonstrated ongoing competence in the International Labour Office classification system to ensure accurate radiographic classifications.

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First introduced in 1930, the International Labour Office (ILO) preliminary guidelines for the classification of radiographs of pneumoconioses were developed to standardize classification methods and facilitate international comparisons of data, and the first formal edition of the ILO International Classification of Radiographs of Pneumoconioses was codified in 1950 (1). Multiple revisions and clarifications were since published, but the basic structure and purpose of the system remains largely intact. The ILO classification system is based on a set of standard radiographs that endeavors to illustrate the patterns of abnormalities and spectrum of severity of the pneumoconioses. Although originally intended for epidemiologic research and worker health surveillance, the system was also internationally adopted for medicolegal purposes.

The 1969 U.S. Coal Mine Health and Safety Act required the National Institute for Occupational Safety and Health (NIOSH) to use the ILO classification system in the national Coal Workers' Health Surveillance Program (CWHSP), which offers periodic medical screening to coal miners (2). To establish a pool of physicians able to use the ILO classification system, NIOSH developed the A Reader and B Reader programs to train and document proficiency of physicians who use the ILO International Classification of Radiographs of Pneumoconioses (3).

A physician can become an A Reader by attending an NIOSH-authorized course on the ILO classification system or by submitting examples of classifications to NIOSH for review. NIOSH B Reader certification requires that the physician demonstrates ongoing proficiency in the ILO classification system by passing a 6-hour certifying examination with subsequent recertification examinations every 4 years (4,5). Because ILO classifications are needed in settings other than the CWHSP, B Readers work in a wide range of research and surveillance settings (4,6–10).

The role of A Readers in the CWHSP was to provide an initial ILO classification at local radiographic facilities, often located in rural areas near mines. This helped to ensure timely recognition and notification of miners about any potentially urgent radiographic abnormalities. After classification by A Readers, films were mailed to NIOSH, cataloged, and mailed to B Readers for a second classification. The film and second classification were mailed back to NIOSH. If there was no substantial agreement between the A and B Readers (2), additional B Reader classifications were required to generate a final determination, which was provided to the miner and used for analysis of surveillance data, and this was previously described (11). B Readers involved in second and subsequent classifications were all employed directly by NIOSH. Historically, the reading process could take several months to complete. In recent years, widespread adoption of digital radiography and electronic image transfer has improved timely access to B Reader and A Reader readings do not contribute to a final determination in the CWHSP when coal miners are screened by using digital chest radiography (12).

Recently, the CWHSP expanded to include surface coal miners, approximately doubling the surveillance population (2). Additionally, on March 24, 2016, the Occupational Safety and Health Administration published a new final rule that mandates periodic chest radiographs for workers exposed to silica and classification of these chest radiographs by NIOSH-certified B Readers (13). Thus, there continues to be a need for physicians who are able to use the ILO system to classify chest radiographs. The purpose of this

Advances in Knowledge

- When evaluating chest radiographs of coal miners, A and B Readers had minimal agreement on technical image quality (κ, 0.0796; 95% confidence interval [CI]: 0.0746, 0.0845) and the distribution of small opacity profusion (subcategory κ, 0.2352; 95% CI: 0.2241, 0.2462).
- A Readers classified more images as "good" quality (prevalence ratio, 1.38; 95% CI: 1.35, 1.41) and identified more radiographs as having evidence of pneumoconiosis (prevalence ratio, 1.22; 95% CI: 1.20, 1.23) and more radiographs with large opacities compared with B Readers (0.17% vs 0.06%, respectively; prevalence ratio, 1.98; 95% CI: 1.67, 2.35).
- B Readers identified pleural plaques, indicative of pleural disease, at a greater frequency than did A Readers (1.58% vs 1.27%, respectively; prevalence ratio, 1.23 [95% CI: 1.19, 1.26).

Implication for Patient Care

- Although the International Labour Office (ILO) classification system is not used for patient care, it plays an important role in medical screening and surveillance of those working in dusty occupations; the results of this study suggest that accurate and reproducible use of the ILO classification system to describe features of chest radiographs is more likely to be achieved by those with documented ability to use the system.

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Abbreviations:
CI = confidence interval
CWHSP = Coal Workers' Health Surveillance Program
ILO = International Labour Office
NIOSH = National Institute for Occupational Safety and Health

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Conflicts of interest are listed at the end of this article.

study was to test the hypothesis that because the proficiency of B Readers is more rigorously documented than the proficiency of A Readers, the results of ILO classifications performed by the groups differ. Therefore, we assessed the level of concordance between chest radiographic classifications of A and B Readers in a national surveillance program offered to U.S. coal miners over an approximately 36-year period.

Materials and Methods

Overview and Study Design

The CWHSP is a surveillance program with nonresearch designation and is exempt from Human Subjects Review Board approval (11-DRDS-NR03). For this retrospective study, data were derived from the CWHSP and restricted to conventional screen-film radiographs submitted during February 1979 to July 2015 (14). All images with a classification by at least one A Reader and one B Reader were included in the analysis. All radiographs were independently classified by A and B Readers for the CWHSP as specified in Title 42 Part 37 of the U.S. Code of Federal Regulations (2). Variables examined included image technical quality, reader medical specialty, small opacity profusion, small opacity shape and size, presence and size of large opacities, presence of pleural plaques, costophrenic angle obliteration, diffuse pleural thickening, and the final determination assigned to the radiograph. Small opacity profusion ranges from 0/0 to 3/+ subcategories, with categories denoted by the whole numbers 0–3 (3). Final determinations of the radiographs may have involved anywhere from two to five independent readings, including a consensus reading by a panel of three B Readers (11).

Statistical Analysis

κ statistics were used to assess agreement between A Readers and B Readers, including unweighted κ values for dichotomous comparisons, Cicchetti-Allison weighted κ values, and 95% confidence intervals (CIs) for comparisons of subcategory small opacity profusion (15). A and B Reader classifications of small opacity profusion subcategory were each also compared with the radiograph's final determination (11). Strength of agreement was assessed by using the following κ values: 0–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1.00, almost perfect (16). In addition, McNemar test of symmetry (Q_M) and Bowker test of symmetry (Q_B) were used to assess symmetry between reader groups (17). Directionality of symmetric differences were evaluated by using the P_{ij}/P_{ji} ratio for contingency tables, where P represents the cell frequency in the i row and j column. P_{ij}/P_{ji} ratio values greater than 1.0 were assigned to quartiles. Prevalence ratios were used to describe general classification differences between A and B Readers. *P* values less than or equal to .05 were considered to indicate statistical significance. We used statistical software (SAS version 9.3; SAS Institute, Cary, NC) for all analyses.

Results

Reader Characteristics

The analysis included 158 370 classifications composed of a classification from an A Reader and B Reader for each of the 79 185 analog chest radiographs that had complete information on small opacity profusion. A total of 287 A Readers and 34 B Readers contributed classifications to the study. Each A Reader classified an average of 275.9 study films (median, 57; range, 1–6305). However, each B Reader classified an average of 2329 study films (median, 1865; range, 14–8950). The physician's medical specialty was known for 94.4% (271 of 287) of A Readers and 100% (34 of 34) of B Readers. A majority of both A and B Readers were radiologists (74.2% [213 of 287] vs 64.7% [22 of 34], respectively; $P = .04$ for difference in proportions). Among the A Reader classifications, 82.2% (65 067 of 79 185) were completed by a radiologist; for B Readers, this figure was 65.0% (51 460 of 79 185; $P < .001$ for difference in proportions).

Reader Agreement on Image Quality

κ values for comparisons between A and B Readers are summarized in the Table. A and B Readers had poor agreement on ILO technical image quality (κ = 0.08; 95% CI: 0.07, 0.08; Q_B $P < .001$). A Readers, when compared with B Readers, were more likely to classify an image as "good" (ILO technical quality category grade 1; prevalence ratio, 1.38; 95% CI: 1.35, 1.41). For 27.2% of pairs (21 549 of 79 185), an A Reader documented film quality as good while the B Reader assigned a lesser grade. In readings where the B Reader indicated the primary defect (6410 of 21 549), 26.5% (1698 of 6410) were because of improper position, 25.7% (1647 of 6410) because of an exposure defect (over or underexposure), and 18.5% (1186 of 6410) because of poor contrast.

Reader Agreement on Small Opacities

Most of the A and B Readers (89.1% [70 574 of 79 185] and 93.1% [73 755 of 79 185], respectively) indicated a small opacity profusion category of 0/0 (Figs 1, 2). However, agreement between A and B Readers regarding the distribution of small opacity profusion was minimal (subcategory κ, 0.24 [95% CI: 0.22, 0.25]; Q_B $P < .001$; and category κ, 0.24 [95% CI: 0.23, 0.25]; Q_B $P < .001$). A Readers tended to identify a higher proportion of radiographs with small opacities suggestive of pneumoconiosis (ie, small opacity profusion of 1/0 or greater) than did B Readers (7.3% [5761 of 79 185] vs 3.4% [2690 of 79 185], respectively; prevalence ratio, 1.22; 95% CI: 1.20, 1.23). A Readers also tended to identify higher categories of small opacity profusion than did B Readers (Fig 2). Figure 2 summarizes A versus B Reader agreement on ILO small opacity classifications by using a contingency table. Directionality of symmetric differences is illustrated by shading according to ratio quartile: darker shading indicates larger ratios. The directionality of the symmetrical differences is heavily weighted toward A Readers identifying higher categories of small opacity profusion.

κ Values and Tests of Symmetry for a Comparison of A Reader and B Reader Image Classifications

Parameter	κ Value	*P* Value, Test of Symmetry
Small opacity profusion subcategory*	0.24 (0.22, 0.25)	<.001
Small opacity profusion category*	0.24 (0.23, 0.25)	<.001
Presence of small opacities†‡	0.23 (0.22, 0.25)	<.001
Large opacity category*	0.50 (0.42, 0.58)	.04
Presence of large opacities†	0.56 (0.49, 0.64)	.002
Presence of pleural abnormalities†	0.16 (0.14, 0.18)	<.001
Film quality grade*	0.08 (0.07, 0.08)	<.001

Note.—Data in parentheses are 95% CIs.

* κ values are weighted and Bowker test of symmetry was used to determine the distribution symmetry and obtain a *P* value.

† McNemar test of symmetry was used to determine the distribution symmetry and obtain a *P* value.

‡ Presence of small opacity profusion 1/0 or greater.

Figure 1

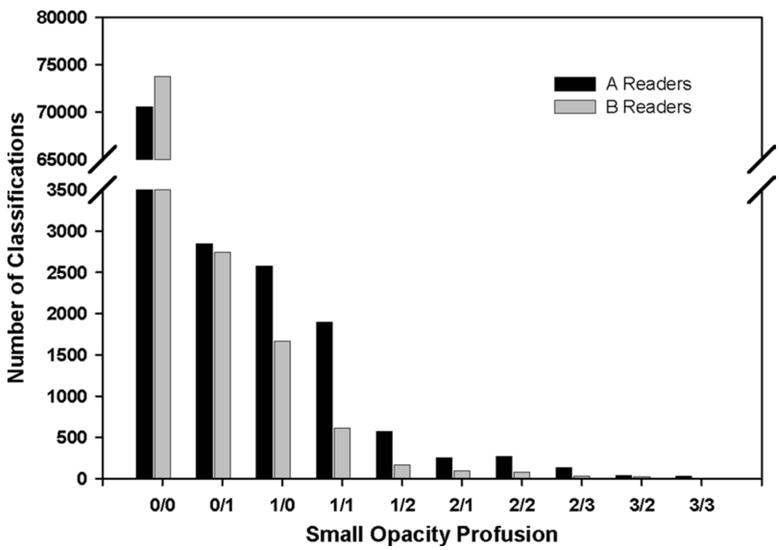

Figure 1: Bar graph shows profusion of small opacities for 158 370 classifications by reader type. Small opacity profusion classifications are standard ILO designations.

When analysis was restricted to A and B Readers who were radiologists, no meaningful effect on agreement for presence or classification of small opacity profusion was observed (κ, 0.23 [95% CI: 0.21, 0.25] vs 0.24 [95% CI: 0.22, 0.25] , respectively; Q_M $P < .001$ and Q_B $P < .001$).

Reader Agreement on Large Opacities and Pleural Plaques

A Readers tended to identify more radiographs with large opacities compared with B Readers (0.17% [131 of 79 185] vs 0.13% [100 of 79 185], respectively; prevalence ratio, 1.98; 95% CI: 1.67, 2.35). A and B Readers showed moderate agreement on the size of large opacities present (κ, 0.50; 95% CI: 0.42, 0.58; Q_B $P = .04$). B Readers, however, identified pleural plaques, indicative of pleural disease, at a greater frequency than did A Readers (1.6% [1251 of 79 185] vs 1.3% [1007 of 79 185], respectively; prevalence ratio, 1.23; 95% CI: 1.19, 1.26).

Reader Agreement with Final Determination

When A and B Readers' small opacity profusion subcategory scores were compared with the final determination, A Readers agreed moderately (κ, 0.52; 95% CI: 0.51, 0.53) and B Readers agreed substantially (κ, 0.63; 95% CI: 0.62, 0.64).

Discussion

Our study, which is based on 36 years of data from the national CWHSP and is composed of 79 185 radiographs and 158 370 physician readings, to our knowledge is the largest to directly assess the importance of readers who demonstrate ongoing proficiency in the ILO classification system. Minimal agreement between A and B Readers with respect to film quality, presence of pneumoconiosis, small opacity profusion, and identification of pleural disease was observed. There was a strong and systematic tendency toward discordant pairs. A Readers identified substantially more radiographs with evidence of pneumoconiosis and higher small opacity profusion than did B Readers, which reinforced the importance of demonstrating ongoing competence in the ILO classification system to ensure accurate radiographic classifications. Although not unexpected, the magnitude, consistency, and strength of this association is noteworthy. B Readers were also more likely to characterize films as being of poorer quality compared with A Readers. If an image has minor or moderate defects but is still classifiable, the reader takes those quality issues into account when determining the presence and characteristics of abnormal shadows on the radiograph. Failure to account for the quality defect or defects could potentially contribute to misclassification of pneumoconiotic abnormalities.

Although the study did not specifically address reasons for a lack of concordance between A and B Readers, it is likely that there are multiple contributing factors. A Readers have not passed the rigorous competency-based

Figure 2

B Readers' Classification (columns) / A Readers' Classification (rows)

A Readers' Classification	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	Total
0/0	**67128**	2042	1081	264	38	11	7	2	1	0	70574
0/1	2504	**194**	111	32	5	3	0	0	1	0	2850
1/0	2134	197	**158**	56	17	10	1	0	0	0	2573
1/1	1280	215	201	**127**	43	16	9	3	1	1	1896
1/2	374	39	59	56	**23**	7	10	2	1	0	571
2/1	116	24	23	33	14	**18**	18	4	2	1	253
2/2	129	19	22	30	17	17	**23**	7	6	0	270
2/3	70	8	6	13	8	8	7	**3**	6	2	131
3/2	14	2	2	2	4	6	3	1	**2**	1	37
3/3	6	0	3	2	0	2	2	7	3	**5**	30
Total	73755	2740	1666	615	169	98	80	29	23	10	79185

P_{ij}/P_{ji} Ratio Quartile
1.01 – 2.00
2.01 –3.33
3.34 – 6.36
6.37 – 35

Figure 2: Contingency table summarizes the agreement on and distribution of ILO small opacity profusion among 79 185 matched A and B Reader classifications.

B Reader examination nor are they required to demonstrate ongoing proficiency in the classification of radiographs for occupational interstitial lung disease. Additionally, A Readers classified far fewer radiographs for the CWHSP than did B Readers during the study time, which may partially account for the lack of agreement we observed. In 1973, Felson et al (18) reached a similar conclusion: Readers with minimal training identified more pneumoconiosis than did experienced readers. Further historic reports that compared experienced radiologists or readers without B Reader certification with B Readers suggested that those who were not B Readers tended to identify pleural and parenchymal abnormalities at higher frequencies than did B Readers (19–23). However, these studies were not designed to assess the potential effect of NIOSH B Reader certification on classifications and were potentially confounded by other systematic differences between the reader groups.

In general, A Readers interpret radiographs as part of their routine clinical duties, and in this study a total of 287 A Readers contributed readings. However, 34 B Readers contributed readings for this study, and most classified thousands of radiographs during the study period. Therefore, these B Readers are highly experienced and classified substantially more radiographs as a group compared with the A Readers (on average, 6.8 times more). Furthermore, specialty training as a radiologist and familiarity with the ILO classification system, as seen with A Reader radiologists in this study, did not appear to ensure satisfactory ILO classifications.

The findings of this study can be evaluated in the context of a recent comparable report. The level of concordance in radiographic classifications observed in the enhanced CWHSP (κ, 0.58; 95% CI: 0.54, 0.62), which uses digital radiographs classified by a relatively small pool of B Readers used directly by NIOSH, is greater than the analog radiographic classifications interpreted by A Readers and B Readers observed in the current study (κ, 0.24; 95% CI: 0.22, 0.25) (24). In addition, the extreme discordant pairs observed in the current study (eg, small opacity profusion subcategories 0/0 vs 3/3) and marginal discordance regarding the presence and size of large opacities were rarely observed in the enhanced CWHSP (24). Thus, when compared in a similar population of workers, the use of only B Readers appears to reduce the variability in classification of radiographs for pneumoconiosis.

This study is subject to limitations. The radiographs used in this study are from a cohort of miners who were exposed to coal mine dust. Inhalation of coal mine dust tends to be associated primarily with parenchymal abnormalities. Therefore, the results from our study may not be translatable to other dust-exposed populations, such as those exposed to asbestos, which tends to be associated with more pleural abnormalities. In addition, the B Readers who provided classifications were employed directly by NIOSH and were chosen based in large part on exceptional performance at the B Reader examination. Thus, their performance documented in this report may be different from that of the entire group of B Readers.

Classification of radiographs for quantitative evidence of dust-related changes remains an important tool in the investigation of workplace hazards, the monitoring of worker health, and for systematically documenting the presence and extent of disease in individuals. NIOSH has outlined four necessary components for attainment of reliable classification of chest radiographs for pneumoconioses, including appropriate methods for image collection and viewing, reader competency, commitment to ethical classification, and proper radiographic reading methods (25). The NIOSH B Reader program is designed to train, test, and maintain these core attributes and competencies (26).

Simply put, before the availability of digital radiography, a miner received a single conventional screen-film radiograph at a participating clinic, and an A Reader at the clinic provided an initial classification and then mailed the classification and radiograph to NIOSH. NIOSH cataloged this information and subsequently mailed the radiograph to a B Reader who provided a second classification and mailed the radiograph and classification back to NIOSH. This lengthy process could have been repeated multiple times, depending on the agreement of classifications, to arrive at a final determination. With the widespread availability and acceptance of digital radiography, NIOSH has implemented reliable electronic image management systems that maintain confidentiality while improving timeliness of reporting results to participants, which thereby eliminates the requirement for local A Readers to provide a final determination for pneumoconiosis. For all radiographs obtained through the CWHSP, a final determination for both small opacity profusion and presence of large opacities requires agreement on at least two independent readings, which minimizes the possibility that discordance between A and B Readers affects the classification results (formal definitions and flow diagrams for the final determination algorithm were previously described [11]). In this study, greater concordance was observed between B Reader classifications and the final determination for a film compared with the agreement between A Reader classifications and the final determination.

Monitoring the respiratory health of workers by using chest radiography and the ILO classification system is an essential component of public health surveillance for occupational lung disease among workers exposed to silica, asbestos, and coal mine dusts. It also remains important for a range of clinical, legal, and scientific purposes. As NIOSH considers how to meet the growing needs in this field, we encourage all interested physicians to consider participating in the B Reader program.

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