Validation of the International Labour Office Digitized Standard Images for Recognition and Classification of Radiographs of Pneumoconiosis

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Rationale and Objectives: Chest radiographs are recommended for prevention and detection of pneumoconiosis. In 2011, the International Labour Office (ILO) released a revision of the *International Classification of Radiographs of Pneumoconioses* that included a digitized standard images set. The present study compared results of classifications of digital chest images performed using the new ILO 2011 digitized standard images to classification approaches used in the past.

Materials and Methods: Underground coal miners ($N = 172$) were examined using both digital and film-screen radiography (FSR) on the same day. Seven National Institute for Occupational Safety and Health-certified B Readers independently classified all 172 digital radiographs, once using the ILO 2011 digitized standard images ($DR_{ILO2011\text{-}D}$) and once using digitized standard images used in the previous research (DR_{RES}). The same seven B Readers classified all the miners' chest films using the ILO film-based standards.

Results: Agreement between classifications of FSR and digital radiography was identical, using a standard image set (either $DR_{ILO2011\text{-}D}$ or DR_{RES}). The overall weighted κ value was 0.58. Some specific differences in the results were seen and noted. However, intrareader variability in this study was similar to the published values and did not appear to be affected by the use of the new ILO 2011 digitized standard images.

Conclusions: These findings validate the use of the ILO digitized standard images for classification of small pneumoconiotic opacities. When digital chest radiographs are obtained and displayed appropriately, results of pneumoconiosis classifications using the 2011 ILO digitized standards are comparable to film-based ILO classifications and to classifications using earlier research standards.

Key Words: Pneumoconiosis; digital radiography; imaging; chest radiograph.

Chest radiographs are recommended for the detection and prevention of pneumoconiosis in workers involved in dusty trades, such as underground mining (1). In clinical practice and public health surveillance, digital chest radiographs (DR) presented on medical-grade monitors have largely replaced the conventional film-screen radiograph (FSR) technology. The *International Labour Office (ILO) Guidelines for the Classification of the Pneumoconioses* has been an invaluable tool for standardization of interpretations of chest radiographs for epidemiologic studies of the pneumoconioses (2). To enhance accuracy and precision in applying the ILO classification scoring system, readers are required to perform a side-by-side comparison of each individual worker's radiograph to one or more prototypical chest images, which illustrate a variety of types and severity of radiographic abnormalities induced by dust inhalation. The ILO classification system includes a standard set of chest images for comparison purposes. Until recently, the ILO classification system only provided a set of standard images in the film-screen radiograph (FSR) format. However, in 2011, the ILO revised its guidelines to "extend the applicability of the Classification to digital radiographic images of the chest" (2). In the 2011 revision of the classification, the ILO includes a set of electronic image files (ILO Standard Digital Images [2011-D]) that was digitized from the film-based standards included in the 2000 revision of the classification.

Prior to the adoption of the ILO Standard Digital Images (2011-D), a series of research studies was undertaken to assess any potential impact of image modality on the outcomes of ILO classifications of chest radiographs (comparing FSR to DR displayed on medical-grade diagnostic monitors) (1,3–5). These investigations obtained both FSR and DR chest radiographs from study participants on the same day. FSR chest radiographs were interpreted using the ILO 2000

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version of the classification system with the traditional film-based standard images. To enable classification of the DR chest radiographs displayed as soft copies on a medical-grade computer monitor, an existing set of the ILO standard films was scanned and digitized (see Franzblau et al. (3) for methods). The resulting image files ("research" digitized standards) were used as the ILO standards for classifying digital images in a number of previous investigations (3–6). These "research" digitized standards appear quite similar to the current set of standard films that are included in the ILO 2000 classification, but were digitized from a prior version of the ILO standard films that had been issued with a black label rather than the current white label. The methods used in these modality studies required that at least two National Institute for Occupational Safety and Health (NIOSH)-certified B Readers[1] interpret each participant's DR chest radiograph presented as a soft copy image side-by-side with the digitized ILO standard radiographs, using two identical medical-grade monitors. In brief, these studies concluded that, with appropriate attention to image acquisition and soft copy display, both of the widely available digital radiography systems[2] can be equivalent to FSR in the visualization and classification of small interstitial lung opacities.

Despite the subjective similarity between the "research" digitized standards and the new ILO Standard Digital Images (2011-D), to our knowledge, there is no objective evidence that classifications acquired using either set would be equivalent. The objective of this study was to evaluate the equivalence of the "research" digitized standards and the ILO Standard Digital Images (2011-D) using paired digital and film chest radiographic examinations performed on the same day in miners from our previous studies. We searched for systematic differences in both the level of abnormality reported and the intra- and inter-reader variability.

MATERIALS AND METHODS

The present study used results from three groups of readings. As part of an earlier research investigation, 1401 miners participating in the NIOSH Enhanced Coal Workers' Health Surveillance Program completed both digital and film chest radiography on the same day (4). For the purposes of that earlier investigation, all the radiographs were independently classified by at least two of eight B Readers, and 172 miners were found to have a profusion of small pneumoconiotic opacities >0/0 by at least one Reader. To investigate a potential effect of image modality on within- and between-reader variability, a follow-up study obtained additional readings for each of the 172 digital and film chest radiographs, using seven of the eight B Readers from the original study (6). Detailed information on study subjects, image acquisition and processing, and image interpretation is available in those previous reports (4,6). The present investigation used the group of 1204 ILO classifications of traditional film-screen radiographs (FSR) obtained during the earlier studies (seven B Readers and 172 miners) and the group of 1204 classifications of digitally acquired chest images performed using the "research" digitized standards (DR_{RES} image set) described previously. For the purposes of the present study, a third group of classifications was obtained for the 172 digital chest radiographs by the same seven B Readers (1204 interpretations), but now using the ILO Standard Digital Images (2011-D) ($DR_{ILO2011\text{-}D}$ image set). Each B Reader performed the additional classification of the digital images in a manner blinded from their own and other readers' previous interpretations. In summary, the present study used these three groups of 1204 B Reader classifications (total 3612 observations) to investigate any potential differences in pneumoconiosis outcomes related to the specific set of standard images used. The results of traditional classification, in which both radiographs and ILO standard images were film-based, were considered the "gold standard" and compared to the classifications of the digital images performed using either the $DR_{ILO2011\text{-}D}$ set or the DR_{RES} standard image set. The central tendency of small opacity profusion, the prevalence of ILO Category 1/0 or greater, and measures of reader variation were assessed using previously described analytic methods (6). Within-reader variability of small opacity profusion category was compared by the standard image set used for classification (FSR vs. $DR_{ILO2011\text{-}D}$ and DR_{RES} vs. $DR_{ILO2011\text{-}D}$), using Cicchetti–Allison weighted κ values and 95% confidence intervals (CIs). In addition, small opacity profusion categories classified using the $DR_{ILO2011\text{-}D}$ set were compared to the DR_{RES} set and FSR by calculating a global interset weighted κ value and Spearman's correlation coefficient, using all readings in aggregate. Finally, small opacity profusion classifications using $DR_{ILO2011\text{-}D}$, DR_{RES}, and FSR were examined using Bowker's test of symmetry. The SAS statistical software version 9.3 (SAS Institute, Cary, NC) was used for all analyses. Data collection for this study was approved by the NIOSH institutional review board (HSRB 12-DRDS-NR02).

RESULTS

Image Quality

Compared to the group of film radiographs, the digital images were more often classified as "good" (ILO technical quality category 1) using either the DR_{RES} set (prevalence ratio [PR], 1.46; 95% CI, 1.35–1.57) or the $DR_{ILO2011\text{-}D}$ set (PR, 1.54; 95% CI, 1.43–1.66) (Table 1). For the digital radiographs, the proportion rated "good" quality was similar, irrespective of the digital standard image set used for the classifications ($P = .13$).

[1] B Readers are physicians who have chosen to document their ongoing competence in the application of the ILO International Classification of Radiographs of the Pneumoconioses by successfully completing a NIOSH-sponsored training and examination program. See The NIOSH B Reader Program. http://www.cdc.gov/niosh/topics/chestradiography/breader.html. Accessed July 2, 2013.

[2] To acquire digital images, currently marketed medical radiography systems use either cassette-based storage phosphor computed radiography or direct readout radiographic imaging.