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Application of the ILO International Classification of Radiographs of Pneumoconioses to Digital Chest Radiographic Images

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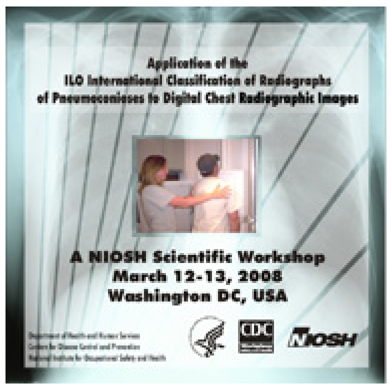

A NIOSH Scientific Workshop

Comparison of Digital Radiographs with Film-Screen Radiographs for Classification of Pneumoconiosis

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Abstract

The International Labor Organization (ILO) system for classifying chest radiographic changes related to inhalation of pathogenic dusts is predicated on film-screen radiography (FSR). Digital radiography (DR) has replaced FSR in many centers, but there are few data to indicate whether DR is equivalent to FSR in identifying and quantifying interstitial and pleural abnormalities. Furthermore, DR images can be printed and viewed on film, so-called 'hard copy' (HC) DR, or can be viewed on a monitor at a computer workstation, so-called 'soft copy' (SC) DR. The goal of this investigation is to assess the equivalency of DR in comparison to FSR for diagnosis and quantification of parenchymal and pleural abnormalities due to pneumoconiosis and other forms of fibrotic lung disease, using the ILO classification system. This report is based on analyses of readings of FSR, HC and SC images from 107 subjects by 6 NIOSH certified B-readers. Overall, there were few differences in the reliability of image classifications across image formats (i.e., most inter-rater kappa values of classifications for FSR, HC and SC images did not differ significantly from each other). Readings of HC images demonstrated a significantly greater prevalence of classifications of small parenchymal opacities compared to FSR and SC (e.g., in adjusted logistic models of the prevalence of small parenchymal abnormalities: the odds ratio of FSR versus HC = 0.72, 95% CI = 0.60-0.86; and, the odds ratio of HC versus SC = 1.26, 95% CI = 1.09-1.46); FSR and SC did not differ significantly. The prevalence of classifications for large opacities differed significantly among all three image formats, with HC>FSR>SC, however, the difference between FSR and SC disappeared when images with 'ax' were included as large opacities. The prevalence of pleural abnormalities differed significantly among all three image formats, with FSR>HC>SC (e.g., in adjusted logistic models of the prevalence of pleural abnormalities: the odds ratio of FSR versus HC = 1.28, 95% CI = 1.08-1.53; the odds ratio of FSR versus SC = 1.59, 95% CI = 1.35-1.88; and, the odds ratio of HC versus SC = 1.24, 95% CI = 1.08-1.42). These results suggest that while the inter-rater reliability of classifications using HC and SC appears to be largely equivalent to FSR, there are some significant differences among FSR, HC and SC with respect to the prevalence of specific outcomes. Based on our results, interpretation of soft copy digital images for small parenchymal opacities and large opacities (with 'ax') appears to result in the same prevalence of ILO classifications as traditional film images, and therefore can be recommended for this purpose.

Introduction

Since the early decades of the 20th century, standard posterior-anterior (PA) film-screen chest radiography (FSR) has been the primary method for screening, diagnosis, medical monitoring and epidemiological study of the pneumoconioses. In the 1930's the International Labour Office (ILO) based in Geneva, Switzerland, became involved in the development and evolution of a scoring system for standardizing the classification of radiographs for pneumoconioses. The system has undergone multiple revisions, most recently in 2000.2 The ILO system is predicated on use of films screen radiology (FSR) remains the most widely used method for classifying chest radiographs for pleural and parenchymal abnormalities related to inhalation of pathogenic dusts.

The goal of the present investigation was to assess the impact of chest radiograph image format, including FSR, soft copy (SC), and hard copy digital imaging (HC), on the results of ILO classifications performed by experienced readers on images of individuals with abnormalities of the lung parenchyma and/or pleura that may result from dust inhalation. In particular, we sought to examine the impact of image format on both the reliability of classification results and the prevalence of findings.

Materials and Methods

This study was approved by the Medical Institutional Review Board of the University of Michigan. One hundred seven subjects were recruited from the University medical clinics and the Michigan and Ohio silicosis registries. A questionnaire recorded demographics, smoking history; occupational history; and past medical history. Height and weight were measured. A standard PA FSR image and a PA DR image were obtained on the same day. No other tests were performed as part of this investigation.

DR chest images were captured on a flat-panel amorphous Selenium digital detector of the Hologic DR 1000C system (Hologic, Inc., Bedford, MA). Each digital image was also printed on a Fuji FM-DPL high quality laser printer (FUJIFILM Medical Systems USA, Inc., Stamford, CT) using Fuji film.

In collection of the PA chest films, standard techniques were employed: 125 kVp, 150 mA, wall unit, 72" (183 cm) SID, all 3 phototimer sensors, using an Agfa film and cassette (Agfa-Gevaert Group, Wilmington, Delaware). The speed of the screen-film system was 200. A scatter rejection grid was uniformly employed.

Each B-reader classified each image in each format (FSR, HC-DR, SC-DR) on two separate occasions. The formats were presented in random order. Within each image format, the images were also presented in random order. There was at least 30 days between each reading cycle for each reader. All readers employed high-resolution physician-quality diagnostic display monitors when reading SC images. With permission from the ILO, the entire set of ILO 1980 standard films was digitized and archived for display side-by-side in classification of soft copy subject images. B-readers recorded classifications using forms consistent with the 2000 revision of the ILO classification system.

Statistical Analyses

Statistical analyses were performed using SAS® for Windows version 9.1 and STATA®.
Kappa statistics were used to compare the reliability of classifications for image quality, parenchymal abnormalities and pleural abnormalities for each image format. Standard errors were calculated using a bootstrap method based on 2,000 replications. Further analyses investigated classification differences across image formats controlling for potential confounders such as age, smoking, and body mass index. A generalized estimating equations (GEE) approach was employed to incorporate the clustering effect in the analysis.

Results

Among the 107 subjects, 80% were male, mean age was 64.6 years, 64% had smoked at some time in their lives, and 56% reported occupational dust exposure. One FSR and one digital image were lost. A total of 3,816 image readings were analyzed (106 images x 3 formats x 6 readers x 2 rounds). The bulk of small opacity profusion scores for FSR images were “0” (43%) and “1” (30%. There was a substantial representation of both small rounded (34%) and small irregular opacities (66%). Fifteen percent of FSR readings indicated the presence of large opacities, and 41% indicated the presence of pleural abnormalities. Summaries of the classification results for the study images overall and for the three image formats are shown in Table 1 for parenchymal abnormalities, and Table 2 for pleural changes. Table 3 displays the results of the GEE model of agreement by image format, both adjusted and unadjusted for potential confounding and competing variables.

Conclusions

Overall, there were few differences in the reliability of image classifications across image formats. Readings of HC images demonstrated significant greater prevalence of small parenchymal opacities compared to FSR and SC; readings of FSR and SC for small parenchymal opacities did not differ significantly. The prevalence of large opacities differed significantly among all three image formats, with HC>FSR>SC, but the difference between FSR and SC disappeared when images with ‘ax’ were grouped with large opacities. The prevalence of pleural abnormalities differed significantly among all three formats, with FSR>HC>SC. The study results suggest that while the reliability of classifications using HC and SC appears to be equivalent to FSR, there are some significant differences among FSR, HC and SC with respect to the prevalence of some key dust-related abnormalities. It is difficult to formulate a consistent recommendation for use of digital chest images with regard to pleural outcomes, based on these results. In contrast, interpretation of soft copy digital images for small parenchymal opacities and large opacities (with ‘ax’) appears to result in equivalent ILO classifications as traditional film images, and therefore can be recommended for this purpose.

Table 1: Results of ILO Classifications Overall and by Chest Radiographic Image Format – Parenchymal changes

	Outcome variable	Overall n	Overall %	Film n	Film %	Hard Copy n	Hard Copy %	Soft Copy n	Soft Copy %
1. Image quality (n=3816*)	1	1130	29%	398	31%	301	24%	431	34%
	2	2282	60%	774	61%	778	61%	730	57%
	3	382	10%	98	8%	175	14%	109	9%
	4 (unreadable)	22	1%	2	0%	18	1%	2	0%

2A. Any Parenchymal Abnormalities (n=3794*)	No	1216	32%	443	35%	358	29%	415	33%
	Yes	2578	68%	827	65%	896	71%	855	67%
2Ba. Shape/Size of Primary Small Opacities (n=2578)	Round(p,q,r)	829	32%	281	34%	280	31%	268	31%
	Irregular(s,t,u)	1749	68%	546	66%	616	69%	587	69%
2Bc. Small Opacity Profusion	0	1529	40%	543	43%	455	36%	531	42%
	1	1158	31%	385	30%	392	31%	381	30%
	2	852	22%	265	21%	306	25%	281	22%
	3	255	7%	77	6%	101	8%	77	6%
2C. Large Opacities	O	3216	85%	1076	85%	1036	83%	1104	87%
	A	228	6%	78	6%	79	6%	71	6%
	B	271	7%	93	7%	101	8%	77	6%
	C	79	2%	23	2%	38	3%	18	1%
2C. Large Opacities	No (0)	3216	85%	1076	85%	1036	83%	1104	87%
	Yes(A/B/C)	578	15%	194	15%	218	17%	166	13%
2C. Large Opacities with ‘ax’	No(0)	3026	80%	1020	80%	969	77%	1037	82%
	Yes(A/B/C/ax)	768	20%	250	20%	285	23%	233	18%

*Images were obtained for each of the three modalities in 107 subjects and were classified on two separate occasions by 6 B Readers. The number of images assessed for film quality is greater than for subsequent outcomes. For a small number readings image quality was rated ‘unreadable’ (n=22). These readings provide no data for subsequent outcomes.
df = degrees of freedom

Table 2: Results of ILO Classifications Overall and by Chest Radiographic Image Format – Pleural changes

	Outcome variable	Overall n	Overall %	Film n	Film %	Hard Copy n	Hard Copy %	Soft Copy n	Soft Copy %
2C. Large Opacities with ‘ax’	No(0)	3026	80%	1020	80%	969	77%	1037	82%
	Yes(A/B/C/ax)	768	20%	250	20%	285	23%	233	18%
3A. Pleural Abnormalities	No	2585	68%	795	59%	868	69%	922	73%
	Yes	1209	32%	475	41%	386	31%	348	27%
3C. Costophrenic angle Obliteration	No	3546	93%	1169	92%	1183	94%	1194	94%
	Yes(right/left)	248	7%	101	8%	71	6%	76	6%
3D. Diffuse Pleural Thickening	No	3620	95%	1199	94%	1201	96%	1220	96%
	Yes(right/left)	174	5%	71	6%	53	4%	50	4%

*Images were obtained for each of the three modalities in 107 subjects and were classified on two separate occasions by 6 B Readers. The number of images assessed for film quality is greater than for subsequent outcomes. For a small number readings image quality was rated ‘unreadable’ (n=22). These readings provide no data for subsequent outcomes.
df = degrees of freedom

Table 3: Adjusted and Unadjusted Comparisons of Prevalence of Outcomes by Image Format (GEE – discrete models)

	Classification comparison	Film versus Hard Copy*	Film versus Soft Copy	Hard versus Soft Copy
1.A: Film Quality (Category 1 v 2,3,&4)	adjusted	0.65 (0.46-0.91)	1.12 (0.84-1.49)	1.72 (1.43-2.08)
	Unadjusted	0.67 (0.49 -0.92)	1.11 (0.85-1.45)	1.66 (1.39-1.96)
1.A: Film Quality (Cat 1&2 v 3&4)	adjusted	0.42 (0.24-0.71)	0.87 (0.50-1.54)	2.10 (1.63-2.70)
	Unadjusted	0.47 (0.31 -0.73)	0.89 (0.56-1.41)	1.87 (1.53-2.30)
2.A: Parenchymal Abnormalities (yes/no)	adjusted	0.72 (0.60-0.86)	0.90 (0.78-1.04)	1.26 (1.09-1.46)
	Unadjusted	0.75 (0.65-0.86)	0.91 (0.80-1.04)	1.22 (1.09-1.35)
2.C: Large Opacities (yes/no)	adjusted	0.83 (0.70-0.99)	1.23 (1.04-1.46)	1.48 (1.24-1.76)
	Unadjusted	0.86 (0.75-0.98)	1.18 (1.03-1.36)	1.38 (1.20-1.58)
2.C: Large Opacities with 'ax' (yes/no)	adjusted	0.79 (0.66-0.94)	1.12 (0.99-1.27)	1.43 (1.22-1.67)
	Unadjusted	0.83 (0.74-0.93)	1.07 (0.98-1.17)	1.29 (1.16-1.44)
3.A: Pleural Abnormalities (yes/no)	adjusted	1.28 (1.08-1.53)	1.59 (1.35-1.88)	1.24 (1.08-1.42)
	Unadjusted	1.30 (1.10-1.53)	1.53 (1.31-1.78)	1.18 (1.04-1.33)
3.C: Costophrenic Angle Obliteration (yes/no)	adjusted	1.41 (0.99-2.00)	1.39 (0.98-1.97)	0.98 (0.80-1.22)
	Unadjusted	1.45 (0.99-2.11)	1.36 (0.93-1.99)	0.94 (0.79-1.12)
3.D: Diffuse Pleural Thickening (yes/no)	adjusted	1.32 (0.97-1.80)	1.43 (1.04-1.98)	1.08 (0.84-1.40)
	Unadjusted	1.35 (0.94-1.95)	1.45 (0.99-2.12)	1.07 (0.84-1.37)

*Estimate of odds ratio (95% confidence interval).

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