Use and Interpretation of Chest Radiographs for Pneumoconioses: B Reading in the 21st Century

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Certified B reader

Objectives

- Become familiar with the historical development of the ILO system of classification of chest radiographs, and how it evolved into its present form
- Provide understanding of the science of how digital radiographs have come to replace film radiographs in application of the ILO system
- Identify weaknesses of the ILO system, in particular problems with identification of pleural abnormalities

What is an occupational disease?

Occupational diseases...stand at one end of the spectrum of work-relatedness where the relationship to specific causative factors at work has been fully established and the factors concerned can be identified, measured, and eventually controlled. At the other end [are] diseases that may have a weak, inconsistent, unclear relationship to working conditions; in the middle of the spectrum there is a possible causal relationship but the strength and the magnitude of it may vary.


What is a “pneumoconiosis”?

- Any non-neoplastic reaction of the lungs to inhaled mineral or organic dust and resultant alteration in structure, but excluding asthma, bronchitis and emphysema (Parkes, page 35)
- “pneumo” = lung, “konis” = dust (Greek)
- Coal, silica & asbestos are the major causes

Occupational Lung Diseases: A Partial Classification

- Pneumoconioses - asbestosis, silicosis, berylliosis
- Occupational asthma - western red cedar, isocyanates, cotton bract dust (byssinosis), rats/lab animals
- Hypersensitivity pneumonitis - farmer’s lung (thermophilic actinomycetes), pigeon breeder’s disease, metal working fluids
- Chemical agents/irritants - ammonia, phosgene, acids, ozone
- Metals - zinc, cadmium, mercury, nickel, copper
- Carcinogens - asbestos, nickel compounds, bis(chloromethyl)ether, radon
- Infectious agents - tuberculosis, Legionnaires disease, anthrax

Historical Development of the ILO System

- Chest radiology entered routine clinical practice in the first decades of the 20th century. Mass screenings were initially practiced for detection of tuberculosis. This approach was also applied among workers with dust exposure. As with other clinical and laboratory procedures used in the practice of medicine, many inconsistencies were noted.
- The evolution of the ILO system has been an effort to enhance validity and reduce inter-observer and intra-observer variability.
Purposes/Uses of the ILO System

- Epidemiological studies of pneumoconioses
- Clinical medicine
- Government requirements (e.g. Chest Roentgenographic Examinations for underground coal miners. Final rule. Federal Register. Wednesday, April 18, 1979;44(76):23084-23085 – people who pass this exam are labeled “B readers”)
- Medical-Legal issues and compensation
- Surveillance/Prevention of pneumoconioses

Historical Development of the ILO System

- 1930: The "Johannesburg Classification" grew out of the International Conference on Silicosis held in South Africa that year. It was the first scheme endorsed by the ILO, and was based on symptoms, radiographic appearance, and work ability; it included 3 stages.

- 1950: The "Sydney Classification" was established following the 3rd International Conference on Pneumoconioses held in Australia. This scheme took account of two types of opacities: discrete small opacities; and, coalescent or massive opacities. Each type was graded by profusion and size. The system focused primarily on disease related to coal and silica.

- 1958: "The International Classification of Persistent Radiological Opacities in the Lung Fields Provoked by the Inhalation of Mineral Dusts", otherwise known as the ILO "Geneva Classification", was the first widely accepted system for classifying chest radiographs with regard to pneumoconioses. It did not address the radiographic characteristics of asbestosis (the system only categorized rounded, not irregular, opacities and did not mention pleural abnormalities), and there were only four profusion categories.

- 1960's: The UICC (International Union Against Cancer) and the Cincinnati Bureau of Occupational Safety and Health (the precursor of NIOSH) developed gradings for irregular opacities and also pleural abnormalities that can be seen among workers exposed to asbestos.
Historical Development of the ILO System

1971: The ILO system is melded with the UICC and Cincinnati system, forming the "ILO U/C International Classification of Radiographs of the Pneumoconioses".

- This system incorporated both rounded and irregular parenchymal opacities, pleural thickening and calcification, large opacities, and the 12 point scale of Liddell.

In the 1970’s the US Congress passed legislation adopting the ILO system for purposes of administering the Black Lung Compensation Program

- Authorized NIOSH to set up a testing and certification process for physicians to demonstrate competency in application of the ILO system (“B reader certification”)

1980: "ILO 1980 International Classification of Radiographs of Pneumoconioses".

- The 1980 scheme incorporates:
  - better standard radiographs
  - mandates the primacy of standard films over textual descriptions of guidelines
  - grading of radiographic quality
  - has a unified profusion score

ILO 2000

- Multiple small improvements:
  - Change in the initial scoring logic
  - Added choices for film quality
  - Better operational definition of diffuse pleural thickening
  - Expanded ‘Other Symbols’

Rationale and Objectives

- Digital chest imaging had replaced film chest radiography in many centers, but the ILO classification system (up through 2000) was predicated solely on film chest radiographs.

- This study evaluated the equivalency of digital chest radiographs (hard and soft copy) with film radiographs using the ILO system.

Franzblau et al. 2009
Materials and Methods

- Digital chest images and film images were obtained on the same day from 107 subjects with a range of parenchymal and pleural abnormalities related to pneumoconiosis.
- Images (film, digital hard copy and digital soft copy) were read twice by six B readers.
- There was no ‘gold standard’ for comparison (e.g., chest CT scans).

Franzblau et al. 2009

Subject Characteristics

<table>
<thead>
<tr>
<th>Subject Characteristics</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>86</td>
<td>80%</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;25 (normal)</td>
<td>28</td>
<td>26%</td>
</tr>
<tr>
<td>25-30</td>
<td>45</td>
<td>42%</td>
</tr>
<tr>
<td>&gt;30</td>
<td>34</td>
<td>32%</td>
</tr>
<tr>
<td>Ever Smoked</td>
<td>68</td>
<td>64%</td>
</tr>
<tr>
<td>Current Smoking</td>
<td>10</td>
<td>9%</td>
</tr>
<tr>
<td>History of dust exposure</td>
<td>60</td>
<td>56%</td>
</tr>
<tr>
<td>Age (mean, sd)</td>
<td>64.7 (11.9)</td>
<td></td>
</tr>
</tbody>
</table>

Total Number of Subjects: 107

Franzblau et al. 2009

Results

- Readings of film and soft copy images were equivalent for small opacity profusion (i.e., prevalence of findings and numeric rating scores).
- Readings of hard copy images showed greater prevalence and numeric scores compared to film and soft copy.

Franzblau et al. 2009
Results

- The prevalence of pleural findings differed significantly among all three image formats: film > hard copy > soft copy

Franzblau et al. 2009

Conclusion

- Film and soft copy images can be recommended for the recognition and classification of dust-related parenchymal abnormalities using the ILO system.
- The role of digital radiography for pleural abnormalities requires additional investigation.

Franzblau et al. 2009

Rationale and Objectives

- The goal of this investigation was to compare inter-reader and intra-reader agreement of the ILO classifications for pneumoconiosis across the three image formats (film, hard copy and soft copy).

Sen et al. 2010

Materials and Methods

- This study used the same methods and data from Franzblau et al (2009)
- A multiple reader version of the inter-reader kappa statistic was compared across image formats.
- Intra-reader kappa comparisons were carried out using an interactive least squares approach, as well as a two-stage regression model adjusting for readers and subject-level covariates.

Sen et al. 2010
Results

- There were few significant differences in the inter-reader and intra-reader agreement across image formats (all related to image quality).
- For parenchymal abnormalities, inter-reader and intra-reader kappa values ranged from 0.54-0.65, and 0.72-0.77, respectively, with no statistically significant differences.

Conclusions

- Film radiographs, soft copy digital images, and hard copy digital images yielded similar reliability (kappa) measures.
- These findings provide further support to the recommendation that soft copy images can be used for recognition and classification of dust-related parenchymal abnormalities using the ILO system.
Rationale and Objectives

- The aim of this study was to determine if digital radiography is comparable to film for classifying pleural abnormalities.

Larson et al. 2011

Materials and Methods

- 200 asbestos-exposed subjects from Libby, Montana
- Digital soft copy and film radiographs, along with chest high resolution computed tomographic (HRCT) scans
- Radiographs were read twice by 7 B readers
- HRCT scans were read once by 3 readers
- ROC curves calculated using consensus HRCT reading as a ‘gold standard’, with models fit to estimate effects of image modality
- Inter-reader and intra-reader kappa statistics were calculated

Larson et al. 2011

Results

- Linear ROC models showed no significant difference between image modalities (digital versus film, P=0.54).
- Area under the curves was essentially the same for film versus digital images.
- Mean crude agreement was 78.3%, and the mean kappa for presence/absence of pleural abnormalities was 0.49.

Larson et al. 2011

Conclusions

- These results indicate that digital soft copy is not statistically different (i.e., kappa) from analog film for the purpose of classifying pleural abnormalities.

Larson et al. 2011

Historical Development of the ILO System

- ILO 2011
- Extended the applicability of the ILO International Classification of Radiographs of Pneumoconioses beyond conventional chest radiographs to digital radiographic images of the chest, including endorsement of new ‘digital’ standard radiographic images.
Identification of Pleural 
Abnormalities

- Pleural findings were incorporated in 1971
- Pleural findings are the most common 
  abnormality among persons exposed to 
  asbestos
- It was recognized early that extrapleural fat 
  may be indistinguishable from plaque on 
  chest radiographs

1 Light R. 2007; 2Vix VA. 1974; 3 Sargent EN. 1984

Background

- Differentiation between subpleural fat and 
  noncalcified pleural plaque is important, but 
  can be difficult on CXRs.
- This study sought to determine if apparent 
  circumscribed pleural thickening on CXRs 
  is related to obesity (as measured by BMI).

Lee et al. 2001
Methods

- Studied 693 former asbestos workers in Australia with film CXRs (not digital)
- All images read by two experienced readers
- BMI was categorized as:
  - ‘normal’: <26 kg/m$^2$
  - ‘overweight’: 26-30 kg/m$^2$
  - ‘obese’: >30 kg/m$^2$

Lee et al. 2001

Results

- Prevalence of pleural thickening:
  - BMI: <26 kg/m$^2$: 8.5%
  - BMI: 26-30 kg/m$^2$: 9.3%
  - BMI: >30 kg/m$^2$: 18.3%

Lee et al. 2001

Conclusion

- Obesity (BMI>30kg/m$^2$) is related to apparent circumscribed pleural thickening on CXR
- There was no ‘gold standard’ (e.g., chest CT) employed

Lee et al. 2001

Impact of BMI on the Detection of Radiographic Localized Pleural Thickening

- Larson T, Franzblau A, Lewin MS, Goodman AB, Antao VC.
- Manuscript submitted to journal 2013

Background

- Subpleural fat can be difficult to distinguish from localized pleural thickening (LPT), a marker of asbestos exposure, on chest radiographs.
- Our goal was to quantify the performance of film and soft copy digital radiographs for LPT detection and to model the risk of a false positive test result with increasing body mass index (BMI).

Methods

- Based on same data as in Larson 2011
- Calculated sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) using HRCT as ‘gold standard’
- Used logistic regression (GEE) to estimate the risk of a false positive result for LPT in relation to BMI while controlling for covariates (age, exposure history, pleural calcification).
Methods

- Radiographic LPT was defined dichotomously as pleural plaque detected in-profile, face-on, on the diaphragm, or at another site and excluded subjects with diffuse pleural thickening (DPT).
- LPT on HRCT was defined dichotomously as abnormalities of the parietal or diaphragmatic pleura detected by at least two of three radiologists, and excluded subjects with visceral pleural thickening.

Results

BMI Category

<table>
<thead>
<tr>
<th>BMI Category</th>
<th>&lt;25 kg/m²</th>
<th>25.0-29.9 kg/m²</th>
<th>30.0-39.9 kg/m²</th>
<th>≥40.0 kg/m²</th>
<th>All Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.51</td>
<td>0.59</td>
<td>0.66</td>
<td>0.53</td>
<td>0.60</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.77</td>
<td>0.60</td>
<td>0.60</td>
<td>0.59</td>
<td>0.66</td>
</tr>
</tbody>
</table>

False (+)  

- 28.0%  
- 42.0%  
- 0.53  
- 0.65  
- 0.48  

False (-)  

- 43.0%  
- 0.25  
- 0.24  
- 0.25  
- 0.27  

PPV  

- 72.0%  
- 0.58  
- 0.48  
- 0.35  
- 0.52  

NPV  

- 57.0%  
- 0.75  
- 0.76  
- 0.75  
- 0.73  

Results shown are for film; digital results are almost identical. PPV, NPV, False positives and false negatives are dependent on sensitivity, specificity, and prevalence of LPT, which was 37.7% (overall) in this study.

GEE Model for Odds of False Positive with BMI as a categorical variable

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Beta estimate</th>
<th>Standard error</th>
<th>Odds ratio (95% CI)</th>
<th>Chi squared</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-2.65</td>
<td>1.22</td>
<td>--</td>
<td>4.71</td>
<td>0.03</td>
</tr>
<tr>
<td>Age</td>
<td>-0.05</td>
<td>0.02</td>
<td>--</td>
<td>7.62</td>
<td>0.01</td>
</tr>
<tr>
<td>Morbidly obese vs. normal</td>
<td>1.90</td>
<td>0.72</td>
<td>6.7 (1.6, 27.7)</td>
<td>6.92</td>
<td>0.01</td>
</tr>
<tr>
<td>Obese vs. normal</td>
<td>1.48</td>
<td>0.59</td>
<td>4.4 (1.4, 14.0)</td>
<td>6.20</td>
<td>0.01</td>
</tr>
<tr>
<td>Overweight vs. normal</td>
<td>0.97</td>
<td>0.64</td>
<td>2.6 (0.8, 9.3)</td>
<td>2.28</td>
<td>0.13</td>
</tr>
<tr>
<td>Exposure (worker or household vs. resident)</td>
<td>-0.73</td>
<td>0.35</td>
<td>0.5 (0.2, 1.0)</td>
<td>4.41</td>
<td>0.04</td>
</tr>
<tr>
<td>Pleural calcification</td>
<td>-0.92</td>
<td>0.31</td>
<td>0.4 (0.2, 0.7)</td>
<td>9.00</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

GEE Model for Odds of False Positive with BMI as a continuous variable

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Beta estimate</th>
<th>Standard error</th>
<th>Odds ratio (95% CI)</th>
<th>Chi squared</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.58</td>
<td>1.40</td>
<td>--</td>
<td>1.28</td>
<td>0.26</td>
</tr>
<tr>
<td>Age</td>
<td>-0.05</td>
<td>0.02</td>
<td>--</td>
<td>6.60</td>
<td>0.01</td>
</tr>
<tr>
<td>BMI</td>
<td>0.06</td>
<td>0.03</td>
<td>--</td>
<td>5.81</td>
<td>0.02</td>
</tr>
<tr>
<td>Exposure (worker or household vs. resident)</td>
<td>-0.71</td>
<td>0.34</td>
<td>0.5 (0.3, 1.0)</td>
<td>4.20</td>
<td>0.04</td>
</tr>
<tr>
<td>Pleural calcification</td>
<td>-0.87</td>
<td>0.30</td>
<td>0.4 (0.2, 0.7)</td>
<td>8.58</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Localized pleural thickening confirmed via HRCT.
GEE Model for Odds of False Negative with BMI as a categorical variable

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Beta Estimate</th>
<th>Standard error</th>
<th>Odds ratio (95% CI)</th>
<th>Chi squared</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.96</td>
<td>1.05</td>
<td>--</td>
<td>3.46</td>
<td>0.06</td>
</tr>
<tr>
<td>Age</td>
<td>0.02</td>
<td>0.02</td>
<td>--</td>
<td>1.90</td>
<td>0.17</td>
</tr>
<tr>
<td>Morbidly obese vs. normal</td>
<td>-0.80</td>
<td>0.71</td>
<td>0.5 (0.1, 1.8)</td>
<td>1.25</td>
<td>0.26</td>
</tr>
<tr>
<td>Obese vs. normal</td>
<td>-0.93</td>
<td>0.56</td>
<td>0.4 (0.1, 1.2)</td>
<td>2.79</td>
<td>0.10</td>
</tr>
<tr>
<td>Overweight vs. normal</td>
<td>-0.81</td>
<td>0.58</td>
<td>0.4 (0.1, 1.4)</td>
<td>1.96</td>
<td>0.16</td>
</tr>
<tr>
<td>Exposure (occupational or household)</td>
<td>0.62</td>
<td>0.34</td>
<td>1.8 (1.0, 3.6)</td>
<td>3.31</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Results

- The odds of a false positive finding of LPT is strongly associated with higher BMI
- Other factors associated with false positive finding of LPT included:
  - Younger age
  - Not having pleural calcification
  - Not having a history of significant asbestos exposure

Conclusions

- Non-calcified LPT is considered to be the most common "marker" of exposure to asbestos.
- Accurate identification of non-calcified LPT is compromised by false positive findings due to subpleural fat, which is strongly related to BMI.
- Due to the magnitude of false positives, the ILO system may need to be modified to not include non-calcified LPT as an outcome.

Where are we now?

- The ILO system has evolved since 1930.
- Film and soft copy digital are equivalent for parenchymal and pleural abnormalities.
- Use of CXRs (digital or film) for identification of non-calcified LPT is suspect.

Conclusions

- Clinicians should be cautious when evaluating chest radiographs of younger, obese persons for the presence of asbestos-related (non-calcified) pleural plaque, particularly in populations having an anticipated low or background prevalence of LPT.
Figure 2. Digital radiograph for a male subject with BMI = 39 kg/m².