

The 60-Film Set with 8-index for Examining Physicians' Proficiency in Reading Pneumoconiosis Chest X-rays

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Abstract: The 60-film set was developed by experts (Expert Group) for examining 8 indices: sensitivity (X_1) and specificity (X_2) for pneumoconiosis, sensitivity (X_3) and specificity for (X_4) large opacities, sensitivity (X_5) and specificity (X_6) for pleural plaque, profusion increment consistency for small opacities (X_7), and shape differentiation for small opacities (X_8) of physicians' reading skills on pneumoconiosis X-ray according to ILO 2000 Classification. The aim of this study was to assess the appropriateness of the exam film set for evaluating physicians' reading skills. 29 physicians (A1-Group) and 24 physicians (A2-Group) attended the 1st and 2nd "Asian Intensive Reader of Pneumoconioses" (AIR Pneumo) training course, respectively, and 22 physicians (B-Group) attended Brazilian training course. After training, they took examination of reading 60-film exam set. The examinees' reading results in terms of 8 indices were compared between the examinee groups and the Expert Group by parametric unpaired *t*-test. The Examinee Group consisting of A1-Group, A2-Group and B-Group was inferior to the Expert Group in all indices. There was no significant difference for X_7 of A1-Group, X_7 and X_8 of A2-Group ($p > 0.05$) compared with the Expert Group. There was a significant difference in X_8 at $p < 0.05$ between A1-Group and A2-Group, in X_3 at $p < 0.05$ between A1-Group and B-Group, in both X_1 and in X_3 at $p < 0.05$ between A2-Group and B-Group. Accordingly, the 60-film set providing 8 indices designed might be a good method for evaluation of the physicians' reading proficiency at different training settings.

Key words: Pneumoconiosis, ILO Classification, Sensitivity, Specificity, Chest X-ray

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Introduction

Pneumoconiosis remains important occupational health problem in developing Asian countries, such as Thailand, China and India¹⁻³. Even in developed Asian countries, new cases of pneumoconiosis are still notified every year. Malignant mesothelioma associated with asbestos exposure recently has been increasingly reported in some Asian countries, e.g. Japan, Korea^{4,5}.

The ILO 2000 International Classification of Radiographs of Pneumoconioses was designed to provide a means of systematically recording the radiographic abnormalities in the chest provoked by inhalation of dusts⁶. This Classification was originally intended as an epidemiologic tool to facilitate international comparison of data on pneumoconiosis. According to national and institutional requirements in countries, the ILO classification has been also used for regulatory screening purposes.

Primary prevention for pneumoconiosis is achieved at the best by eliminating dust exposure, and is the most effective in three levels of prevention, i.e. primary, secondary and tertiary prevention, but requires various initiatives, e.g. dust reduction, respirators wearing and so on. Secondary prevention is achieved through the development of an organized screening program that allows the early detection of diseases⁷. Health surveillance and medical screening can provide immediate protection of the health of workers once they show the early signs of pneumoconiosis and are removed from the dusty workplace⁸, and then the permanent injury can be prevented.

The “Asian Intensive Reader of Pneumoconioses” (“AIR Pneumo”, Web address: <http://airp.umin.jp/>) program has been established with an aim to upgrade the skills of physicians in developing Asian countries in reading pneumoconiosis radiographs according to the ILO 2000 International Classification of Radiographs of Pneumoconioses and to contribute to the implementation of the ILO/WHO Global Program for Elimination of Silicosis (GPES). Participants who pass the examination of reading chest X-rays carried out during 3 d AIR Pneumo Training Course are issued with certificates by the AIR Pneumo Committee. The re-certification is to take place every five years.

The examination with reading a set of 60 subject films took place at three times in different countries to date. The 8 examination indices include sensitivity for pneumoconiosis, specificity for pneumoconiosis, sensitivity for large opacities, specificity for large opacities, sensitivity for pleural plaque, specificity for pleural plaque, profusion consistency for small opacities, and shape differentiation

for rounded opacities and irregular opacities. We renamed profusion consistency as “profusion increment consistency” because profusions ranged from 0, 1 to 3 in the exam films, which simulate profusions increasing in the occupational settings depending on the dust exposure and lung fibrosis^{9,10}.

The purpose of the current study was to assess the appropriateness of the 60-film exam set in evaluating the proficiency of physicians in reading pneumoconiosis chest X-ray.

Subjects and Methods

Examinees

There were firstly 29 physicians (A1-Group) coming from Thailand, Japan, Vietnam, China and the Democratic Republic of Congo participating in the 1st AIR Pneumo Training Course in Chest Disease Institute, Thailand from Dec. 17th to 19th, 2008. The average working time of examinees was about 18.96 ± 9.31 yr, and radiologists accounted for 48.28% (14/29). There were 24 physicians (A2-Group) attending the 2nd AIR Pneumo Training Course in Chest Disease Institute, Thailand from Dec. 20th to 22nd, 2010. The working time of examinees was 9.08 ± 7.91 yr, and radiologists accounted for 37.5% (9/24). There were secondly 22 Brazilian physicians (B-Group) participating in the Brazilian Training Course in August 2009. The average working time of Brazilian physicians were 24.23 ± 9.25 yr, the radiologists accounted for 27.27% (6/22), and others were chest physicians or industrial medicine doctors. There was no significant difference in the proportion of number of physicians in profession among the three groups. The Examinee Group (n=75) consisted of A1-Group (n=29), A2-Group (n=24) and B-Group (n=22).

Questionnaire

During the training course, each examinee in all groups was distributed with the questionnaire to fill in the information on gender, working period and the speciality. The questionnaires of examinees were collected.

The 1st Pilot AIR Pneumo Training Course for 3 d in Dec, 2008 and the 2nd Pilot AIR Pneumo Training Course for 3 d in Dec, 2010

The teaching method, syllabus, teaching films and practice films, and the exam film set used in the 2nd Pilot AIR Pneumo Training Course were same as those used in 1st Pilot AIR Pneumo Training Course. In brief, on the first

one and half days, based on the course syllabus, the tutors who had been trained in advance by ILO panel made presentations of teaching films by showing pneumoconiotic findings to examinees. In the afternoon of the second day, there were 4 to 5 h for film self-practice. An interactive teaching style (ACR Felson's methods) was used, in which the lecturer firstly asked the physicians to read the practice films in comparison with ILO standard films of pneumoconiosis by themselves, and thereafter gave the correct answer to them. In this way, the physicians could improve their proficiency in interpretation and strengthen technique on the classification of pneumoconiosis, and also could learn how to fill in the reading sheets in an appropriate way. On the 3rd day, physicians completed reading a set of 60 exam films for 3 h.

Brazilian training course for 3 d in Aug, 2009

This course was a national training course for reading pneumoconiosis chest X-ray, which was organized by Brazilian experts. ILO panel and domestic experts gave lectures with presentations of example films on the same topics as AIR Pneumo course for examinees. There was lack of an established timing self-practice; only several films were used for self-practice in the end of the course. After 2 d of lectures, the physicians took examination by reading the 60 exam films, which were the same as those used in AIR Pneumo examination.

Selection of 60 exam film set from candidates

There were 310 candidate films collected by the experts from Thailand, Japan and China including 12 "USA National Institute for Occupational Safety and Health B" reader (NIOSH B reader) certificated experts. The normal films without pneumoconiosis accounted for 1/3. Each normal case was confirmed that he or she had no mineral dust exposure history, and each case of pneumoconiosis was confirmed that he or she had mineral dust exposure history by the experts who provided the chest X-ray. The parenchymal abnormalities of pneumoconiosis were confirmed to relate with mineral dust exposure, neither due to pneumonia nor to other diseases. History taking by experts concentrated the mineral dust exposure without concerns on the job category of the patient.

The experts who provided the candidate chest films had got oral agreement from patients and had transferred the copyright to AIR Pneumo Committee. The information of all patients on the films were deleted technically, including the clinical identification numbers, age, jobs, dates of taking chest X-ray and names of hospitals. These chest films

only were used for the current research purpose.

From the 310 candidate films, there were 132 candidate films of quality 1 or 2 with or without pneumoconiosis selected by the experts. Then the 132 candidate films including again normal films about in 1/3 were circulated for reading among international experts in Asian and other countries including 12 NIOSH B readers. The experts were blinded of the information that whether the cases have occupational exposure history or not. The experts independently read the chest films and recorded the chest findings according to ILO 2000 International Classification of Radiographs of Pneumoconioses. From the 132 candidate films, 60 films as an examination set including 50 films and 10 repeated films were selected on the basis of the statistical analysis results from the 12 NIOSH B readers' readings and additionally on the basis of consensus opinions from core experts. Film selection criteria and the numbers of films required for assessment of 8 indices are described in Table A1 in the Appendix.

Assessment algorithm

The correct answer of each film was decided based on the result of statistical analysis from the reading by the 12 NIOSH B reader experts (Expert Group), and taken as gold standard to test the physicians' proficiency in reading pneumoconiosis chest X-ray for 8-index. Algorithm of assessment for physician's reading proficiency in 60-film exam set is shown in the Appendix.

Statistical Analyses

The working periods of the examinee groups from the questionnaire was analyzed by One-way ANOVA test, and was compared by Bonferroni multiple comparisons for the differences between examinee groups. The comparative analysis of the reading results in terms of 8-index data for examinee groups in comparison with the Expert Group were conducted by parametric unpaired *t*-test by SPSS version 16.00 (SPSS Inc., USA). The *p* value <0.05 was considered as a significant difference. The profusion increment consistency of the Expert Group was also calculated in comparison with the mode of profusion of each film based on the criteria of 1 minor category allowance.

Results

Comparison for the working period between the examinee sub-groups

The working periods of the examinees in three exam-

Table 1. The comparison for the working periods of the three examinee groups by One-way ANOVA analysis

	A1-Group* (n=26)	A2-Group (n=24)	B-Group (n=22)	F	p
Working period (yr)	18.96 ± 9.31	9.08 ± 7.91	24.23 ± 9.25	17.553	<0.05

Data were expressed in Mean ± SD, SD=Standard deviation. *One examinee in A1-Group had not filled in questionnaire, and 2 examinees forgot to fill in the information of working period. Comparative analysis by Bonferroni method in One-way ANOVA test: A1-Group vs A2-Group, $p=0.001$; A1-Group vs B-Group, $p=0.131$; A2-Group vs B-Group, $p<0.001$.

Table 2. The comparative analysis for the indices of the examinee groups and the expert group

Index	Examinee Group (n=75)	A1-Group (n=29)	A2-Group (n=24)	B-Group (n=22)	Expert Group (n=12)	
X ₁	M ± SD	0.935 ± 0.076*	0.947 ± 0.059*	0.957 ± 0.038* [#]	0.894 ± 0.108*	1.000 ± 0
	Range	0.613~1.000	0.774~1.000	0.871~1.000	0.613~1.000	1.000~1.000
	Median	0.968	0.968	0.968	0.919	1.000
X ₂	M ± SD	0.926 ± 0.089*	0.912 ± 0.100*	0.938 ± 0.078*	0.932 ± 0.085*	0.992 ± 0.019
	Range	0.650~1.000	0.650~1.000	0.700~1.000	0.750~1.000	0.950~1.000
	Median	0.950	0.950	0.950	0.950	1.000
X ₃	M ± SD	0.924 ± 0.117* ^{###}	0.939 ± 0.109* ^(*,#)	0.963 ± 0.071* [#]	0.864 ± 0.145*	1.000 ± 0
	Range	0.444~1.000	0.667~1.000	0.778~1.000	0.4444~1.000	1.000~1.000
	Median	1.000	1.000	1.000	0.889	1.000
X ₄	M ± SD	0.970 ± 0.051*	0.977 ± 0.048*	0.978 ± 0.026*	0.953 ± 0.069*	1.000 ± 0
	Range	0.781~1.000	0.781~1.000	0.902~1.000	0.805~1.000	1.000~1.000
	Median	1.000	1.000	0.976	1.000	1.000
X ₅	M ± SD	0.861 ± 0.144*	0.847 ± 0.147*	0.898 ± 0.118*	0.838 ± 0.163*	1.000 ± 0
	Range	0.333~1.000	0.444~1.000	0.556~1.000	0.333~1.000	1.000~1.000
	Median	0.889	0.889	0.889	0.889	1.000
X ₆	M ± SD	0.930 ± 0.077*	0.925 ± 0.089*	0.932 ± 0.076*	0.935 ± 0.065*	1.000 ± 0
	Range	0.633~1.000	0.633~1.000	0.700~1.000	0.800~1.000	1.000~1.000
	Median	0.967	0.967	0.933	0.967	1.000
X ₇	M ± SD	0.698 ± 0.132*	0.710 ± 0.120	0.708 ± 0.129	0.670 ± 0.150*	0.808 ± 0.186
	Range	0.333~0.967	0.333~0.867	0.500~0.967	0.400~0.900	0.300~0.967
	Median	0.733	0.733	0.733	0.683	0.867
X ₈	M ± SD	0.876 ± 0.118*	0.845 ± 0.142*	0.920 ± 0.080* ^{***}	0.867 ± 0.106*	0.958 ± 0.066
	Range	0.417~1.000	0.417~1.000	0.667~1.000	0.667~1.000	0.792~1.000
	Median	0.917	0.833	0.917	0.896	1.000

M=Mean, SD=standard deviations. X₁: Sensitivity for pneumoconiosis, X₂: Specificity for pneumoconiosis, X₃: Sensitivity for large opacities, X₄: Specificity for large opacities, X₅: Sensitivity for pleural plaque, X₆: Specificity for pleural plaque, X₇: Profusion increment consistency, X₈: Shape differentiation for small opacities. *Examinee Group vs Expert Group, $p<0.05$, *A1-Group vs Expert Group, $p<0.05$, *A2-Group vs Expert Group, $p<0.05$, *B-Group vs Expert Group, $p<0.05$, #A1-Group vs B-Group, $p<0.05$, #A2-Group vs B-Group, $p<0.05$, ###Examinee Group vs B-Group, $p<0.05$, ***A1-Group vs A2-Group, $p<0.05$.

inee sub-groups were shown in Table 1. The One-way ANOVA test showed that there was a significant difference in the working periods among the three examinee sub-groups. There were significant differences in the working periods between A1-Group and A2-Group, and between A2-Group and B-Group, while there was no significant difference between A1-Group and B-group.

Difference of the reading proficiency between Examinee Group and the Expert Group

All indices of the Examinee Group were significantly lower than those of the Expert Group ($p<0.05$), as shown in Table 2.

Difference of reading proficiency between the examinee sub-group and Expert Group

There was no significant difference in the profusion increment consistency between A1-Group and Expert Group ($p=0.051$), while there were significant differences in other 7 indices between A1-Group and Expert Group, shown in Table 2.

There was no significant difference in profusion increment consistency for small opacities ($p=0.068$) and shape differentiation for rounded and irregular small opacities ($p=0.166$) between A2-Group and Expert Group, while there were significant differences in other 6 indices between these two groups.

All indices of the B-Group were significantly lower than those of the Expert Group ($p<0.05$).

Difference of reading proficiency between the examinee sub-groups

There was a significant difference in shape differentiation for small opacities between the A1-Group and A2-Group ($p<0.05$), while there was no significant difference for other 7 indices between these two groups, see Table 2.

There was a significant difference ($p<0.05$) in sensitivity for large opacities between A1-Group and B-Group, while there was no significant difference in other 7 indices between these two groups.

There were significant differences ($p<0.05$) in sensitivity for pneumoconiosis and sensitivity for large opacities between A2-Group and B-Group, while there was no significant difference in other 6 indices between these two groups.

Discussion

The AIR Pneumo Program emphasizes the proficiency of the examinee in differentiating between absence and presence of small opacities on the chest films, therefore the indices of sensitivity for pneumoconiosis and specificity for pneumoconiosis were applied to evaluate the physicians reading skill. The films with profusion 1/1 or over and profusion 0/0 were subjected to test the physicians' proficiency of sensitivity for pneumoconiosis and specificity for pneumoconiosis, shown in Appendix. Since profusion 2 or over of small opacities on film can be easily recognized by examinees, much more films ($n=21$) with profusion 1/1 than those ($n=10$) with profusion 2 or over were included in the exam 60-film set.

The profusion increment consistency is a newly developed index in the current study; the purpose of developing

this index is to test the proficiency of physicians in recognition of any profusions of small opacities. For each in the exam films, since the profusion of small opacities recorded by experts was not in normal distribution, the mode of profusion by experts was taken as the correct answer in connection with the preceding study taking the mode as a gold standard for selection ILO 1980 standards⁽¹⁾. Thus we considered an 1 minor category allowance for profusions on the examinee side and, on this condition, developed the new index of profusion increment consistency, application of one minor category allowance may be quite instructive, understandable and encourageous both to examinees and examiners. This can contribute to transparency of AIR Pneumo algorithm.

The practice and examination with reading pneumoconiotic changes on films of profusion 0/1 or 1/0 could provide a chance for the physicians to strengthen competence for identifying pneumoconiosis at an early stage. And for this purpose, several boundary cases were selected for the exam films. Considering big variations of the profusion recorded by experts for these several boundary cases, the mode of profusion could not be decided for such cases. As a result, there was only one boundary case with profusion mode 1/0 being subjected to calculation of the profusion increment consistency.

It was noted that there were two experts have lower profusion increment consistency, e.g. 0.333. If we excluded the twos, 10 of 12 of NIOSH B readers had a better profusion increment consistency of 0.877 ± 0.072 , which showed a clearly significantly higher value than that in A1-Group (0.710 ± 0.120) and that in A2-Group (0.708 ± 0.129) ($p<0.01$). This suggests that profusion increment consistency was very tough even to some in the Expert Group. The future task for the AIR Pneumo Program is to improve the instructing skills for the profusion increment consistency and to strengthen this skill among the experts, too.

Considering the small number of each trainee group at courses, the different professions and the working periods in each training group, heterogeneity of physicians' specialty with unequal distribution of physician interest and lack of an established timing for self-practice in B-Group, it was difficult to assess the effectiveness of the three training courses. The purpose of the current study was not to assess the effectiveness of the three training courses, but to assess the appropriateness of the 60-film exam set in evaluating the reading proficiency of physicians. Even so, irrespective of our aim, it remained difficult to control these factors possibly affecting the examination results

Table 3. Comparison for the indices between the current program examination criteria and NIOSH B reader examination criteria

Aspect in proficiency	Index in NIOSH B reader examination	Index in the current program examination
Accuracy for small opacities	$20 - (\text{Percent of FP} + \text{Percent of FN}) \times 0.4$	Sensitivity for pneumoconiosis Specificity for pneumoconiosis
Accuracy for large opacities	$20 - (\text{Percent of FP} + \text{Percent of FN}) \times 0.4$	Sensitivity for large opacities Specificity for large opacities
Accuracy for pleural abnormalities	$10 - (\text{Percent of FP} + \text{Percent of FN}) \times 0.2$	Sensitivity for pleural plaque Specificity for pleural plaque
Accuracy for profusion	Over reading/under reading tendency $= (1 - \bar{X}_{\text{Candidate}} - \bar{X}_{\text{Panel}}) \times 10^*$ Inconsistency index of profusion $= (1.8 - \text{SD}) \times 30^{**}$	Profusion increment consistency: 1 minor category allowance for the profusion of each case
Shape differentiation for small opacities	(-)	Shape differentiation for small opacities
Other diseases	(+)	(-)

FP=False positive, FN=False negative. $\bar{X}_{\text{Candidate}}$ represent the average of profusion of all 125 films by individual candidate in the 12 point scale, \bar{X}_{Panel} represent the average of profusion of all 125 films by the expert panel, for each of which the mean profusion by 10 experts was used as correct answer for profusion. $^{**}\text{SD}$ represent the standard deviation of differences between the candidate’s and panel’s classification. The profusion of 12-subcategory are converted into integers, e.g.0/1=1,1/0=2.

with the 60 film sets.

The current results showed that A1-Group and A2-Group were inferior to experts group in 7 and 6 indices out of 8 indices, respectively. A1-Group might be superior to the B-Group as shown in 1 index, i.e., sensitivity for large opacities, and A2-Group might be superior to the B-Group as shown in 2 indices, i.e., sensitivity for pneumoconiosis and sensitivity for large opacities. A2-Group might be superior to the A1-Group as shown in 1 index, i.e., shape differentiation between rounded and irregular small opacities.

The One-way ANOVA analysis with Bonferroni multiple comparisons method of the working periods between groups showed that A2-Group had less working experience than A1-Group and B-Group. As a result, especially for the Bonferroni analysis, the A2-Group with the shorter experience period did have significant proficiency in one or two indices than A1-Group or B-Group with longer periods. The index values did not seem to relate to the working periods. Then taken together, the working period might not impact proficiency assessed by the 60 exam film set.

The 8 indices in the AIR Pneumo examination and the indices in the NIOSH B reader examination¹²⁾ are shown in the Table 3 for comparison. Similarly to the profusion increment consistency in the current AIR Pneumo study, profusion accuracy is most highly emphasized in USA NIOSH B reader examination¹³⁾.

Small irregular opacities from lung fibrosis are fre-

quently seen in asbestosis¹⁴⁾. Therefore it is important for occupational physicians to identify the chest finding of asbestosis. It was the first time for AIR Pneumo Program to include the new index of shape differentiation for small opacities into examination. This proficiency might be able to contribute to prevent asbestosis effectively.

One limitation of this study was that, as to the shape index, there were 20 films with purely rounded small opacity (R/R) subjected, while there were only 4 films with purely irregular small opacity (IR/IR) subjected. Including more films with irregular small opacity for the shape index may be appropriate in the future AIR Pneumo Program.

According to the results of the current study, further improvements for the future AIR Pneumo Program are to be anticipated: increase the number of boundary cases for index of profusion increment consistency; more films with purely irregular opacities will be included for the index of shape differentiation. The profusion increment consistency is the toughest index to achieve, suggesting the AIR Pneumo training course to be further improved for this proficiency in the future.

In conclusion, the 60-film set providing 8 indices designed might be a good method for evaluation of the physicians’ reading proficiency at different training setting.

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Appendix

The course syllabus in the AIR Pneumo standardized training course for reading chest X-ray of pneumoconiosis

The course syllabus which the tutors delivered to the participants included the following topics: the introduction to ILO (2000) International Classification of Radiographs of Pneumoconioses, the epidemiology and control of pneumoconiosis in Thailand and Asian countries, the quality of radiographs, the rounded and irregular parenchymal opacities, the large opacities, the pleural abnormalities and the additional symbols.

60 exam films with correct answers and selection criteria

In this context with the selection described as in Table A1 below, the correct answers for each exam film were decided according to the reading results of 12 NIOSH B readers. As to the profusion in 12-scale, the mode of profusion among 12 readers is regarded as the correct answer for profusion¹¹⁾.

About 1/3 of the 60 exam films are normal with profusion 0, and 2/3 films are with profusion equal to or more than 1/1. The films with conflicting recording as presence or absence of large opacities by experts were excluded to subject to the indices of sensitivity and specificity for large opacities. The films with conflicting recording as presence or absence of pleural plaque by experts were excluded to subject to calculation of sensitivity and specificity for pleural plaque. The films subjected to indices of large opacities or pleural plaques were in complete agreement only for their presence and absence by all 12 NIOSH B readers, the size of large opacities recorded by experts may be different. There are 9 films absolutely with large opacities and 41 films definitely without large opacities. Nine films with plaques, and 30 films without plaque were subjected to the indices of the specificity and sensitivity for pleural plaque.

Algorithm of assessment for physicians' proficiency on classifying pneumoconiosis chest X-ray with the 60 film set

(1) Sensitivity and specificity for pneumoconiosis:

- 1) Definition: Sensitivity for pneumoconiosis is the proportion of true pneumoconiosis cases that are correctly identified as pneumoconiosis by examinees in the test. Specificity for pneumoconiosis is the proportion of truly normal cases that are identified as normal by examinees¹⁵⁾.
- 2) Criteria for the films with pneumoconiosis or normal films: On expert's side, the film with the mode of the profusion 1/1 or over recorded by 12 NIOSH B experts is regarded as positive of pneumoconiosis, and the film with the mode of the profusion 0/0 recorded by 12 experts is considered as normal. On examinee side, the film recorded as profusion 1/0 or over by examinee is regarded as positive of pneumoconiosis, and the film recorded as profusion 0/0 or 0/1 is considered as normal.
- 3) Equations for calculating the sensitivity and specificity for pneumoconiosis:

Sensitivity for pneumoconiosis

Number of films classified as positive for pneumoconiosis by examinee, which were also classified as positive for pneumoconiosis by examinee by all 12 NIOSH B experts

Number of films classified as positive for pneumoconiosis by all 12 experts (n=31)

Specificity for pneumoconiosis

Number of films classified as non-pneumoconiosis by examinee, which were also classified as normal by all 12 NIOSH B experts

Number of films classified as normal by all 12 experts (n=20)

- 4) Allowance for correctly recording for pneumoconiosis: For the positive pneumoconiosis film, the profusion recorded as 1/0 or over by examinee is regarded as correct. For the normal film, the profusion 0/0 or 0/1 is regarded as correct.

(2) *Sensitivity and specificity for large opacities*

- 1) Definition: Sensitivity for large opacities is the proportion of the true large opacities cases that are correctly identified as presence of large opacities by examinees in the test. Specificity for large opacities is the proportion of the truly no large opacities cases that is correctly identified as absence of large opacities by examinees.
- 2) Criteria for the film with large opacities or without large opacities: The film recorded as any of the large opacities A, B, C by all 12 NIOSH B experts is considered as the true large opacities film. The film recorded as absence of large opacities A, B, or C by all 12 NIOSH B experts is considered as the truly no large opacities film.
- 3) Equations for calculating the sensitivity and specificity for large opacities

Sensitivity for large opacities

Number of films recorded as presence of large opacities by examinee, which were also recorded as presence of large opacities by all 12 NIOSH B experts

Number of films recorded as presence of large opacities by all 12 NIOSH B experts (n=9)

Specificity for large opacities

Number of films recorded as absence of large opacities by examinee, which were also recorded as absence of large opacities by all 12 NIOSH B experts

Number of films recorded as absence of large opacities by all 12 NIOSH B experts (n=41)

- 4) Allowance for correctly recording large opacities: For the true large opacities film, the presence of large opacities as any of A, B and C recorded by examinee is regarded as correct. For the truly no large opacities film, the absence of large opacities recorded by examinee is regarded as correct.

(3) *Sensitivity and specificity for pleural plaque*

- 1) Definition: Sensitivity for large opacities is the proportion of the true pleural plaque cases that are correctly identified as presence of pleural plaque by examinees in the test. Specificity for pleural plaque is the proportion of the truly no pleural plaque cases that is correctly identified as absence of pleural plaque by examinees.
- 2) Criteria for the film with or without pleural plaque: The film recorded as presence of pleural plaque in profile, face on, diaphragm, or other sites by all 12 NIOSH B experts is considered as true pleural plaque film. The film recorded as the absence of pleural plaque for any sites by all 12 NIOSH B experts is considered as the truly no pleural plaque film.
- 3) Equations for calculating the sensitivity and specificity for pleural plaque

Sensitivity for pleural plaque

Number of films recorded as presence of pleural plaque by examinee, which were also recorded as presence of pleural plaque by all 12 NIOSH B experts

Number of films classified as presence of pleural plaque by all 12 NIOSH B experts (n=9)

Specificity for pleural plaque

Number of films classified as absence of pleural plaque by examinee, which were also recorded as absence of pleural plaque by all 12 NIOSH B experts

Number of films recorded as absence of pleural plaque by all 12 NIOSH B experts (n=30)

- 4) Allowance for correctly recording pleural plaque: For the true pleural plaque film, the presence of the pleural plaques in profile, face on, diaphragm or other sites recorded by examinee is considered as correct. For the truly no pleural plaque film, the absence of pleural plaque recorded by examinee is considered as correct.

(4) *Profusion increment consistency*

- 1) Definition: Profusion increment consistency is the consistency between the profusion of film recorded by experts and that recorded by examinee.
- 2) Criteria for the film subjected to profusion increment consistency: The films with profusion 1/0 or higher were included.
- 3) Equation for calculating the profusion increment consistency

$$\frac{\text{Number of the films correctly classified the profusion by examinee within 1 minor category allowance among those films subjected to profusion increment consistency}}{\text{Number of the films subjected to profusion increment consistency (n=30)}}$$

- 4) Allowance for correctly classifying profusion: For each film, the profusion recorded by examinee is compared with the mode of profusion by experts, the profusion within 1 minor category differences below or above is considered as allowance for correct classifying, shown as Table A2.

(5) *Shape differentiation for small opacities*

The primary/secondary shape and size of small opacities recorded by 12 NOSH-B certificated experts were summarized and categorized into 4 shape pattern i.e., R/R, R/IR, IR/R, IR/IR, in which R represent the rounded shape: p, q and r, and the IR represent the irregular shape s, t and u.

- 1) Definition: Shape differentiation for small opacities is the consistency between the shape of small opacities recorded by examinee and that by 12 NIOSH B experts in terms of 4 shape pattern.
- 2) Criteria for films subjected to shape differentiation: For each film, the number out of 12 experts who recorded either of the categories as R/R, R/IR, IR/R, IR/IR were counted and considered. If the majority experts in 10 or more among 12 experts recorded the shape pattern as R/R, and only 2 or less experts recorded the shape as either of R/IR, IR/R, or IR/IR, such film is considered as the purely rounded opacity film. On the other hand, if the majority experts in 10 or more recorded the shape pattern as IR/IR, and only 2 or less experts recorded the shape as either of IR/R, R/IR, or R/R, such film is considered as purely irregular opacities film. There are 24 films subjected to the index of shape differentiation, including 20 films with purely rounded opacities and 4 films with purely irregular opacities.
- 3) Equation for calculating the shape differentiation for small opacities

$$\frac{\text{Number of the films correctly classified for the shape by examinee among those films subjected to shape differentiation}}{\text{Number of the films subjected to films subjected to shape differentiation (n=24)}}$$

- 4) Allowance for the correctly recording shape pattern: For the films with purely rounded shape R/R, both the shape of R/R or R/IR recorded by examinee were considered as allowed shape pattern that agreed on the shape pattern recorded by experts. For the film with purely irregular shape IR/IR, the shape IR/IR and IR/R recorded by examinee were considered as allowed shape that was agreed on the shape pattern recorded by experts. The crude agreement for shape differentiation between experts and examinees were shown as in Table A3.

Table A1 60 exam films grouped by criteria and index for correct answer

Criteria	Number of films	Index
Profusion	0/0 (n=20)	Sensitivity and specificity for pneumoconiosis
	Boundary cases (n=4) (profusion mode=0/1)	Not subjected to profusion increment consistency
	Boundary cases (n=4) (profusion median=1/0 or 0/1), (mode not determined due to big variations of profusion)	Not subjected to profusion increment consistency
	Profusion 1/0 (n=1)	Profusion increment consistency,
	Profusion 1 (1/1 or 1/2)(n=21)	Sensitivity and specificity for pneumoconiosis
	Profusion ≥ 2 (n=8)	
	Profusion >1 (n=2), mode was not determined due to big variation of profusion	Not subjected to profusion increment consistency, subjected to pneumoconiosis index
Pneumoconiosis	Yes (n=31), No (n=20)	Sensitivity and specificity for pneumoconiosis
	Boundary cases (n=9)	Not subject to pneumoconiosis criteria
Shape	Purely rounded opacity (R/R*) films (n=20), Purely irregular opacity (IR/IR**) films (n=4)	Shape differentiation for small opacities
Large opacities	Films with large opacities (n=9) (A: n=3, B: n=5, C: n=1); Films without large opacities (n=41)	Sensitivity and specificity for large opacities
Pleural plaque	Films with plaque (n=9); Films without plaque (n=30)	Sensitivity and specificity for pleural plaque

*R represents the rounded shape of small opacities including p, q, r. **IR represents the irregular shape of small opacities including s, t, u.

Table A2 Allowances for profusion increment consistency of each film

Expert's correct answer	Examinees' answer allowed		
1/0	0/1	1/0	1/1
1/1	1/0	1/1	1/2
1/2	1/1	1/2	2/1
2/1	1/2	2/1	2/2
2/2	2/1	2/2	2/3
2/3	2/2	2/3	3/2
3/2	2/3	3/2	3/3
3/3	3/2	3/3	3/+
3/+	3/3	3/+	

Table A3 Allowed agreement for shape differentiation for small opacities

Experts' answer	Examinees' answer			
	R*/R	R/IR**	IR/R	IR/IR
R/R	Y	Y	N	N
IR/IR	N	N	Y	Y

*R: p, q, r, **IR: s, t, u.