

## The Japanese Classification of Computed Tomography for Pneumoconioses with Standard Films: Comparison with the ILO International Classification of Radiographs for Pneumoconioses

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**Abstract:** The Japanese Classification of Computed Tomography for Pneumoconioses with Standard Films: Comparison with the ILO International Classification of Radiographs for Pneumoconioses: Narufumi SUGANUMA, *et al.* Department of Environmental Health, School of Medicine, Fukui Medical University—Objective: Computed tomography (CT) has recently come to be used for personal diagnosis of pneumoconioses and preliminarily for epidemiological purposes. This study aimed to compare the diagnosis of pneumoconioses by the Japanese Classification of CT for Pneumoconioses (Hosoda-Shida Classification) with that by the ILO International Classification of Radiographs of Pneumoconioses (ILO 1980 standard). The Hosoda-Shida Classification is also described in this article. Subjects and Methods: CT and chest posterior-anterior X-ray (CXR) were performed in 21 subjects with an occupational history of mining, and 6 subject without exposure to any risk of pneumoconiosis. Three radiologists independently described the findings of CT and CXR according to both the Hosoda-Shida Classification and the ILO 1980 standard, respectively. Results: At least two of the three readers agreed in determining both the profusion and the type of small rounded opacities in 96% (26/27) of the CT films. The inter-reader agreement of profusion was satisfactory

with the Cohen's weighted kappa value of 0.57 to 0.71. The weighted kappa for CXR and CT in describing the profusion and the type of small rounded opacities were 0.70 and 0.77, respectively. Conclusion: The Hosoda-Shida Classification for pneumoconioses is shown to be reliable and compatible with the ILO 1980 standard in describing the profusion and the type of small opacities.

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**Key words:** Pneumoconiosis, Computed tomography, Standard films, Classification, ILO, Small rounded opacities

Pneumoconioses, pulmonary fibrosis caused by inhalation of silica, coal particles or asbestos, still have a great effect on occupational health all over the world. Among causative substances, asbestos is well acknowledged carcinogen of lung cancer and malignant mesothelioma, and silica was classified as a group I carcinogen by the International Agency for Research on Cancer (IARC) in 1996<sup>1)</sup>. Although patients with early lesions of pneumoconioses usually do not have pulmonary dysfunction, they should be screened periodically for possible pulmonary malignancy.

Radiological examination is essential for the diagnosis of pneumoconioses for both clinical and epidemiologic purposes. The International Classification of Radiographs of Pneumoconioses published by International Labour Office (ILO), which was first developed in 1950 and had

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its last major revision was done in 1980<sup>3)</sup> (ILO 1980 system), is a widely accepted standard of radiograph for the diagnosis of pneumoconiosis. Minor revision done in 1998 was mainly introduced quadrant films and some changes in the way of describing pleural plaques.

This classification system is widely used in the United States, where the National Institute of Occupational Health and Safety (NIOSH) and the American College of Radiology (ACR) collaborate to educate physicians to read radiographs of pneumoconioses according to the ILO 1980 system and certify as B-readers those who reached a certain level of diagnostic ability. European nations usually use the system for classifying pneumoconiosis, whereas some Asian countries, such as China and Japan, for instance, have modified the ILO 1980 system or developed their own classification system to cope with the national demand.

In Japan, workers with possible exposure to occupational dust are legitimately screened with a chest posterior-anterior radiograph, which is classified in the Japanese Classification of Radiographs of Pneumoconioses (JC). Kusaka *et al.* investigated the differences between JC and ILO 1980 system and found that JC had a higher category than ILO 1980 system in describing pneumoconiotic lesions<sup>3)</sup>. Although there are few people with severe findings in chest radiographs, more than 1,400 workers are still newly enumerated in Japan every year as subjects with pneumoconiotic changes for the prevention of progress under Pneumoconiosis Law and governmental compensation provisions.

In addition to the radiographs, computed tomography (CT) has recently been introduced for personal diagnosis of pneumoconioses and preliminarily for epidemiologic purposes. Since CT detects finer anatomical structure than radiography, it is expected to increase the sensitivity of diagnostic measures for this disease. The superiority of CT to radiography in detecting pleural thickening or plaque was the first to be discussed among the radiographic manifestations of pneumoconiosis<sup>4, 5)</sup>. Making the most of High Resolution Computed Tomography (HRCT), it is possible to describe morphological changes in the secondary lobule of the lung<sup>6)</sup>, in which the early characteristic lesions of pulmonary fibrosis are observed.

The clinical diagnosis of pneumoconiosis by use of CT varies among physicians. In some cases CT findings were overestimated as pneumoconioses for the lack of knowledge about pneumoconiotic changes on CT. A classification system of CT for pneumoconioses must be developed to provide reliable diagnosis of the disease with high reproducibility.

As for the diagnosis of pneumoconioses by CT in Japan, Y. Hosoda and H. Shida, leading Japanese experts of radiological diagnosis of the diseases, had developed

the Japanese Classification of Computed Tomography for Pneumoconioses (Hosoda-Shida Classification) in 1995<sup>7)</sup>. This article aimed to describe the Hosoda-Shida Classification and to compare diagnosis of pneumoconioses by the novel classification of CT with that by ILO 1980 system of radiograph, as it is desirable for the newly developed classification to be compatible with the long used system.

## Subjects and Methods

### Subjects

Twenty-one male workers with exposure to occupational dust and 6 males without any exposure to the risk of pneumoconioses were studied by means of the same examination protocol. The age of the exposed subjects ranged from 49 to 72, with a median of 62 yr old. Their median number of exposure years was 19, and the range was 5 to 42. All patients were ex-smokers except for one current smoker. The median age of the unexposed subjects was 56 yr and the range was 53 to 60. There were no smokers among 6 controls. The exposed subjects had been traced at the Department of Environmental Health, Fukui Medical University School of Medicine.

### Computed tomography

All CT scans were performed on a GE9800 (General Electrics) scanner. Conventional CT (CCT) scans were obtained with 10 mm collimation at 1cm intervals from the apex to the base of the lungs and five to seven high resolution CT (HRCT) scans were subsequently obtained with 1.5 mm collimation through the upper, middle and lower thorax. Both CCT and HRCT scans were reviewed at window values most appropriate for pulmonary parenchyma (window level - 500 to - 700 and window width 1000 to 2000). Imaging was performed while patients were supine and holding their breath at maximal inspiration.

### Chest posterior-anterior X-ray

High voltage posterior-anterior radiograph of the chest (CXR) was taken from each of the subject.

### Hosoda-Shida classification

Japan Industrial Safety and Health Association (JISHA) developed the Hosoda-Shida Classification in 1993, according to which one can describe CT with pneumoconiotic changes referring to the 13 standard films. The standard films for categories 1, 2 and 3 of the profusion of small rounded opacities are shown in Fig. 1. The reading sheet for this classification is reproduced in Table 1. The readers describe the CT findings referring to the standard films guided by the checklist on the sheet. The terms used in the reading sheet are explained in the attached appendix 1. The Hosoda-Shida classification also provides recommendation for imaging parameters



**Fig. 1.** Some of the standard films of the Hosoda-Shida Classification of CT for Pneumoconioses. The profusion of small rounded opacities increases downward. Top: category 1, type q'; middle: category 2, type q'; above: category 3, type r'. Eggshell calcification of hilar and mediastinal lymph nodes is seen.

(Appendix 2).

#### *Trial reading*

Three expert radiologists, who have been diagnosing pneumoconioses for more than 10 years, independently described the findings of CT and CXR according to the Hosoda-Shida Classification for pneumoconioses and to the ILO 1980 system, respectively. The materials on exposed and unexposed subjects were given blindly to the readers. The CT findings were coded on the reading sheet described above. Part of both classification systems concerning small rounded opacities is reproduced in Table 3.

#### *Statistical evaluation*

Cohen's weighted kappa statistics were used to assess inter-reader agreement among the three readers and agreement between the two diagnostic measures. In comparing the CT and CXR readings, we took each reading agreed on by two or more readers. Kappa statistics exceeding 0.75 were interpreted as excellent agreement, values between 0.4 and 0.75 as fair to good agreement, and values less than 0.4 as poor agreement<sup>8)</sup>.

## **Results**

#### *Inter-reader agreement*

At least two of the three readers agreed in diagnosing both the profusion and the type of small rounded opacities consisting primary lesions in 96% (26/27) of the CT films (Table 2). The weighted kappa statistics on describing the profusion of rounded opacities showed good agreement between each pair of readers with a range of 0.57 to 0.71.

#### *CT vs. CXR*

Comparison between the CXR and CT readings on the profusion and the type of the small rounded opacities shows compatibility of the two diagnostic methods (Tables 3 and 4). The weighted kappa value between the two diagnostic measures on the profusion was 0.70 and that on the type of small rounded opacities was 0.77. Thus, agreement of CXR and CT readings on the profusion was fair to good, and that on the type of small rounded opacities was excellent. There was a case classified as category 1 in profusion by CT but category 0 according to CXR.

## **Discussion**

Most proposed grading systems or classifications using CT only dealt with a specific type of pneumoconiosis, especially asbestosis<sup>9,10)</sup>. Even the German classification developed by Kraus *et al.*, which attempted to describe all types of pneumoconioses, does not have appropriate standard films for the description but only has some reference films of example cases<sup>11)</sup>. As far as the literature

**Table 1.** The Hosoda-Shida Classification reading sheet. Translated and reproduced from reference 7) with permission

Reading Sheet for Hosoda-Shida Classification of CT for Pneumoconiosis

Patient's ID

Reader's code

1. Small Rounded opacities	(1) Profusion (0 1 2 3)	<input type="checkbox"/>
	(2) Shape/size (p' q' r' y <sup>1</sup> )	<input type="checkbox"/> / <input type="checkbox"/>
2. Irregular Opacities	(1) Profusion (0 1 2 3)	<input type="checkbox"/>
	(2) Shape	
	(a) Interlobular septal thickening	<input type="checkbox"/>
	(b) Subpleural curvilinear shadow	<input type="checkbox"/>
	(c) Band-like shadow	<input type="checkbox"/>
	(d) others	<input type="checkbox"/>
3. High Density Area	(1) Density <sup>2</sup>	<input type="checkbox"/>
	(2) Volume loss	<input type="checkbox"/>
	(3) Extent <sup>3</sup> (0 1 2 3)	<input type="checkbox"/>
4. Emphysema	Extent <sup>3</sup> (0 1 2 3)	<input type="checkbox"/>
5. Bullae, Bleb	Extent <sup>3</sup> (0 1 2 3)	<input type="checkbox"/>
6. Honeycombing	Extent <sup>3</sup> (0 1 2 3)	<input type="checkbox"/>
7. Diffuse Pleural Thickening	Existence	<input type="checkbox"/>
8. Pleural Plaque	Existence with calcification	<input type="checkbox"/> <input type="checkbox"/>
9. Lymph Node Swelling	Existence with calcification	<input type="checkbox"/> <input type="checkbox"/>
10. Others		<input type="checkbox"/>

Ramarks

1) y: Dot-like lesions or branching structures situated in the subpleural zone

2) Density: 1 Ground glass; 2 Moderate; 3 Consolidation

3) Extent: 1 Localised; 2 Moderate; 3 Extensive

**Table 2.** The agreement among three readers on the profusion and the type of small rounded opacities on CT

Profusion	all/at least 2	Type	all/at least 2
0	9/15	0	8/12
1	0/3	p'	1/14
2	2/7	q'	0/1
3	0/1	r'	0
NA	1	NA	0

NA: did not reach agreement

**Table 3.** Agreement and Relationship for the profusion of small rounded opacities in CXR and CT

Profusion by CT <sup>b</sup>	Profusion by CXR <sup>a</sup>				Total
	0	1	2	3	
0	15	0	0	0	15
1	1	1	1	0	3
2	0	4	3	0	7
3	0	0	1	0	1
NA <sup>c</sup>	0	0	0	1	1
Total	16	5	5	1	27

<sup>a</sup>CXR: chest posterior-anterior X-ray; <sup>b</sup>CT: computed tomography; <sup>c</sup>NA: not agreed

has been reviewed, this Hosoda-Shida classification is the only systematic classification system in the world that attempts to describe any type of pneumoconioses referring to standard films which represent the profusion and the type of small rounded opacities and irregular opacities. Standard films have proven to be essential to the

classification system to maintain good inter-reader and intra-reader agreement in the development of the ILO classification of radiographs for pneumoconiosis<sup>12)</sup>. The

**Table 4.** Agreement and Relationship for the type of small rounded opacities in CXR and CT

Type by CT <sup>b</sup>	Type by CXR <sup>a</sup>				NA <sup>c</sup>	Total
	0	p	q	r		
0	15	0	0	0	0	15
p'	1	1	4	1	0	7
q'	0	0	3	0	1	4
r'	0	0	0	1	0	1
Total	16	1	7	2	1	27

<sup>a</sup>CXR: chest posterior-anterior X-ray; <sup>b</sup>CT: computed tomography;

<sup>c</sup>NA: not agreed

Hosoda-Shida Classification should be a tentative candidate for the international classification of CT for pneumoconioses.

A former study that we performed with technegas ventilation single photon emission CT (SPECT), which made it possible to show impairment of ventilation in images on same plane as CT, validated the CT and HRCT readings by the prototype Hosoda-Shida classification. The profusion of the rounded opacities and the extent of emphysema, bullae of CT or HRCT in patients with silicosis were independently correlated with regional ventilation impairment<sup>13)</sup>.

The detection rate for early changes by CT among the CXR negatives was not so high in this study. CT detected rounded opacities among 10 cases with CXR negative but exposed to dust in one type p' case. The detection rate of 10% was lower than in other reports that dealt with early detection of nodular or fibrotic changes derived from pneumoconiosis. Gevenois *et al.*<sup>14)</sup> showed that CT could detect micronodules in 40% of the 0/0 and 0/1 cases in coal workers. The reason for this relatively modest superiority of CT to radiography in detecting small rounded opacities in this study is that the aim of this study is different from the others with a high detection rate. We did not gather many CXR borderline cases of pneumoconiosis but have chosen enough cases to investigate inter-reader agreement by different diagnostic measures.

The radiographic findings for pneumoconioses have been mainly divided into silicotic nodules and fibrotic changes caused by asbestosis. Small rounded opacities predominant in the upper to middle lung fields are a well-known manifestation of silicosis, whereas irregular opacities predominant in the lower lung field are compatible with asbestosis. Shida H *et al.* have shown radiologic and pathologic characteristics of mixed dust pneumoconiosis whose radiograph and CT have hazy rounded opacities often accompanied by fibrotic changes and its pathological section shows interstitial fibrosis<sup>15)</sup>.

Using CT and HRCT more and more early lesions of fibrotic changes will be detected among various types of pneumoconioses. Dividing the type of small opacities into small rounded and irregular opacities may not be enough to describe the character of each type of pneumoconiosis, especially in the CT classification.

The tentative classification of CT for pneumoconioses proposed by Hosoda Y and Shida H showed acceptable inter-reader agreement and compatibility with the ILO 1980 system. Despite the good compatibility of Hosoda-Shida classification with the ILO 1980 system in describing the profusion and the type of the small rounded opacities, there are some points to be clarified. First, the fair to good agreement between each pair of the readers was obtained because the subjects included in this study were limited to those at risk of silicosis. As the tested findings for CT were also limited to the profusion and the type of the small rounded opacities, the comparison between the Hosoda-Shida system and ILO 1980 became much easier than taking all the findings into consideration. Other materials manifesting the findings of irregular opacities, large opacities and pleural plaques need to be examined according to this classification system.

Although the kappa values are of fair to good agreement, three pairs of the readers showed different level of agreement. One of the possible way to increase the inter-reader agreement will be to require readers to use standard films strictly in reading the material films. How to prepare the standard films needs further elaboration to encourage readers to use standard films in classifying CT films. Selected slices of standard CT films may be edited to reconstruct a few CT sheets, which would be easier to use in clinics. There should be clear description, including tutorial schema of typical findings, of standard films attached to explain which shadow is to be referred to.

In describing the fibrotic changes, CT or HRCT have so much higher resolution than radiographs that subtle emphysema or honeycombing can be easily detected, so

that irregular opacities, emphysema and honeycombing should all be considered. Some kind of scoring system other than that of profusion or extent may be needed to express the severity of fibrosis in CT film. Vehmas *et al.* have developed a grading system for asbestos-related disease integrating fibrotic findings on HRCT into grades 0 to V<sup>16)</sup>. They have used the system to screen more than 700 workers at risk.

The terms used in the Hosoda-Shida classification may be insufficient to describe all types of fibrotic changes. It would be appropriate not to list all the findings on the reading sheet but to limit them to several major findings. The glossary<sup>17, 18)</sup> proposed by Webb, WR *et al.* may be adopted as containing standardised terms for the purpose of avoiding misunderstanding in describing findings and harmonising existing classification systems.

In Conclusion, the Hosoda-Shida Classification of CT for pneumoconioses has been shown to be reliable and compatible with the ILO 1980 system for CXR in describing the profusion and the type of small rounded opacities. Through harmonising already developed classification systems, including the Hosoda-Shida classification, development of an International CT Classification for Pneumoconiosis is feasible.

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**Appendix 1.** The manual for describing the CT findings according to the Hosoda-Shida Classification. Translated and reproduced from reference 7) with permission.

CT findings of pneumoconioses were described assessing following 1 to 9 comprehensively.

1. Small rounded opacities

Small rounded nodules not exceeding 10 mm in diameter are defined as small rounded opacities. The profusion was decided after reviewing all the slices available referring to standard film No. 2, which represents category 2 of profusion. Films with nodules less in number than in film No. 2 were coded as category 1, and films with more nodules than the category 2 standard were coded as category 3. The types of the small rounded opacities were divided into p', q' and r', which are small, medium and large, respectively, in accordance with the radiograph classification.

Type y was introduced to indicate dot-like lesions or branching structures situated in the subpleural zone. These findings, clearly different from silicotic nodules, were observed not only in asbestosis but also in mixed dust pneumoconiosis.

2. Irregular opacities

Irregular opacities were defined as linear or reticular shadows, which are not recognisable as small nodules. As CT detects various types of linear or reticular opacities, those cannot be classified into (a) to (c) were described at (d) others in detail. The profusion of the irregular opacities was decided referring to appropriate standard film in same manner as that of small rounded opacities.

(a) Inter-lobular septal thickening

A linear shadow which is caused by thickening of inter-lobular septa. Usually observed as a vertical line from the pleura, and sometimes forming a polygonal matrix.

(b) Subpleural curvilinear shadow

A linear or band-like shadow which runs parallel to the pleura within 1 cm in distance.

(c) Band-like shadow

Any band-like shadow which does not agree with definition (a) nor (b).

3. High density area

All types of high attenuation areas those exceed 1 cm in diameter, usually larger than a lobule, are included in this criterion. They are classified according to the density, shape and the characteristics of the rim.

(1) Density

- 1 Ground-glass opacity: High attenuation with homogenous density. Underlying pulmonary vessels should be clearly identified in the

lesion.

- 2 High attenuation with density higher than 1 but lower than 3.
- 3 Air-space consolidation: High attenuation that results in obscuration of underlying pulmonary vessels. An air-bronchogram may be observed in the lesion.
- 4 Conglomeration: High attenuation as dense as 3 with an irregular rim which implies distortion of surrounding tissue, that is, polymorphic high attenuation consisting of many small rounded opacities. This criterion is consistent with the large opacity in radiograph.

(2) Volume loss

Existence of the volume loss was assessed by the presence of distortion of surrounding tissue structure. Air-space consolidation of Density 3 does not have distortion by definition. However, in the CT of pneumoconiosis pure consolidation rarely exists alone, but sometimes accompanied by emphysematous lesion.

4. Emphysema

Low attenuation without distinct walls. The extent of the lesion was classified as follows:

- 1 Subtle lesion with intact structure. Includes para septal emphysema\*.
- 2 Involves medium large area with thinner pulmonary vessels.
- 3 Involves large area with extremely thinner pulmonary vessels and distorted surrounding structure.

\*Para septal emphysema: localised low attenuation found only in subpleural portion of secondary lobule less than 1 cm in diameter.

5. Bulla, Bleb

Round low attenuation with thin wall. Usually larger than 1 cm in diameter. Its extent was classified as follows:

- 1 Localised in subpleural area.
- 2 Larger than extent 1, but smaller than extent 2.
- 3 Involves medium layer to the core of the lung.

6. Honeycombing

Cystic lesion less than 1 cm in diameter surrounded by thick walls. Usually accompanied by rosary-like or tram-line like lesion suggesting the presence of bronchoectasis. Most lesions have volume loss.

Their extent were classified as follows:

- 1 Localised in subpleural area.
- 2 Larger than extent 1, but smaller than extent 2.
- 3 Involves medium layer to the core of the lung.

7. Pleural thickening

Band-like lesion with the density of soft tissue goes parallel to the thoracic wall. The length of the lesion often exceeds several centimeters with or without partial calcification. The width of the lesion should

- |   |   |
|---|---|
| <p>be even without nodular formation.</p> <p>8. Pleural plaque<br/>Localised lesion with the density of soft tissue parallel to the thoracic wall. Calcification of the</p> | <p>lesion was reviewed in CT by soft tissue algorithm.</p> <p>9. Lymphadenopathy<br/>Mediastinal or hilar lymph nodes larger than 10 mm in diameter were detected as lymphadenopathy.</p> |
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**Appendix 2.** The recommended imaging parameter of CT/HRCT for pneumoconioses. Translated and reproduced from reference 7) with permission.

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Recommendation for the CT/HRCT technique for Pneumoconiosis

I. Apparatus

Reconstruction algorithm with high-spatial frequency should be used to avoid blurring of the picture.

II. Scan technique

1. Scan time: Less than 2 sec. Preferable if less than 1 sec.
2. kV: Around 120 kV.
3. mA: 100–300.

III. Collimation and interval

Conventional CT should be taken with 5–10 mm collimation. In the case in need of more thorough diagnosis, high resolution mode with 1–2 mm collimation should be taken. The entire thorax should be imaged with 12 to 15 slices at 1–2 cm interval.

HRCT is useful in detecting the emphysematous or fibrous changes, although the tangent of pulmonary vessels and small rounded opacities should be carefully differentiated.

IV. Filter function that is most appropriate for displaying lung fields should be chosen.

V. Expression of lung fields

1. Lung fields: The most appropriate filter for showing pulmonary parenchyma should be chosen.
2. Mediastinum and pleura: The filter for soft tissues should be chosen.

VI. Displaying window

For pulmonary parenchyma, window width with 1000–1500 HU and window level with –600 to –800 are recommended.

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