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

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# CR and FPD DR chest radiographic image parameters for the pneumoconioses: the Japanese approach and experience

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**Summary**

Recently the Ministry of Health, Welfare and Labour, Japan (MHWL-J) has approved the flat-panel detector (FPD) Digital Radiography (DR) for its use in the legal medical judgment of pneumoconiosis. Computed radiography, requiring an imaging plate, has been already approved for the purpose since 2001. The pre-storage parameters for gray scale processing and spatial frequency processing are critical to the visualization of the image, more than the post-storage parameters, like window level and width. In this paper, we describe the approach that the Pneumoconiosis Taskforce for the MHWL-J has taken to decide the appropriate imaging parameters of FPD DR for the medical judgment of the presence of pneumoconiotic opacities as demanded by the Pneumoconiosis Law in Japan. In order to obtain comparable images, pre-storage processing considerably affects image, and storage using P-values as stated in DICOM part 14 is strongly recommended.

**Introduction**

Digital alternatives in radiography, both computed radiography (CR) and digital radiography (DR), have been well accepted in clinical use. Their benefits include easy handling, less chemical waste, less space for storage, and better latitude compared to the conventional film-screen (FS) radiography and they have almost replaced the FS radiography in the most of the big hospitals in Japan. The increasing use of Picture Archiving and Communication Systems (PACS) in such hospitals prompted the trend toward digitization of radiography.

This trend has influenced the medical screening of pneumoconioses and corresponding legal judgments, which directly affect compensation of the patient. The Pneumoconiosis Law (1) in Japan demands that workers exposed to dust take medical examinations including chest radiographs. Each radiograph is reviewed by a physician

according to the Japan Classification of Radiographs of Pneumoconiosis (2), which is almost parallel to the ILO International Classification of Radiographs of the Pneumoconioses (ILO/ICRP) (3, 4).

Recently the Ministry of Health, Welfare and Labour, Japan (MHWL-J) has approved the flat-panel detector (FPD) DR for its use in the legal medical judgment of pneumoconiosis (5). The other type of digital radiographic techniques, the CR that needs the storage phosphor, *i.e.* the imaging plate (IP), has been approved since 2001 (6). Because images from CR are somewhat dissimilar from FS radiographs, the MHWL-J had selected a number of typical case sets to supplement the Japan Pneumoconiosis Standard Radiographs. However, it is a complex task to introduce new technology that can be substituted for conventional FS radiographs. The Pneumoconiosis Law uses the scale from the radiographic judgment to categorize dust-exposed workers, and these categories determine whether or not compensation is applicable. Thus, revision of this law has been a socially sensitive issue. The taskforce was required to assure that the new modality provides similar results to the previous approach in categorizing pneumoconiotic opacities.

This article aims to describe the approach taken by the FPD DR Taskforce to determine the appropriate imaging parameters for FPD DR for the medical judgment of the presence and amount of pneumoconiotic opacities, as demanded by the Pneumoconiosis Law in Japan. Our approach has been, firstly, to decide the appropriate FPD DR parameters for the judgment of pneumoconiosis, and secondly to assess the appropriateness of the parameter through a reading trial using the proposed parameters. For the former purpose we took Canon CXDI as an example and made a thorough investigation on its imaging parameters. After we had decided the appropriate imaging parameters, we performed a reading trial comparing FS radiographs and hard copies of FPD DR images. The approach was similar to that taken in deciding required

parameters for CR, leading to approval of CR for pneumoconiosis judgments in 2001. As there are multiple venders producing the FPD DR systems, the taskforce demanded that venders submit typical pneumoconiosis images taken by their systems. Specific parameters that correspond to the taskforce recommendations were sought. The taskforce also decided upon a process to approve the new apparatus for the legal medical judgment of pneumoconioses.

## I. Evaluation of appropriate FPD DR parameters for judging the grade of pneumoconiosis using Canon FPD DR system

As full technical support from engineers was available from Canon, Inc. as well as Canon has the leading share of the FPD DR market in Japan, the CXDI (Canon, Inc., Tokyo) was chosen as the product to fully assess its imaging parameters. All the FPD DR images and FS radiographs were obtained after receiving written informed consent from the subjects in the hospitals that had collaborated in this study. As new cases of pneumoconioses are not abundant in Japan, most of the cases were from the two major institutes that had operated an FPD DR system for a number of years.

In order to decide the appropriate parameters, four typical cases of silicosis were selected from the FPD DR case archives, each representing the mid-category of profusion 0, 1, 2, and 3. Imaging parameters concerning the gray scale processing and the spatial frequency processing were changed one by one to assess the difference caused by the parameter modification. The taskforce for CR approval had taken a similar approach to assess the comparability of FS chest radiographs and CR hard copies. The middle column of the **Table 1** shows appropriate ranges for the gray-scale and spatial frequency processing that was recommended by the MHWL-J taskforce for CR approval in the legal medical judgment of pneumoconiosis in 2001 (6). The comparable imaging parameters for each vender of the CR and CXDI (Canon, Inc., Tokyo) are listed in **Table 2**. The FPD

DR Taskforce performed the group-review using five experienced physicians, changing the parameters one by one for all the four cases. **Table 3** compares the two parameter sets: one was recommended by the vender that keeps the image within the CR Taskforce guideline and the other was approved by the FPD DR Taskforce after group-reviews of the images printed using various parameters.

Five experienced physicians, who were either radiologists or pulmonologists and served as regional or central Pneumoconiosis Examination Physicians appointed by the MHWL-J, reviewed hard copies of FPD DR images processed with various parameters, and provided a consensus decision regarding whether the image was appropriate for pneumoconiosis judgment or not. After the group readings, the taskforce decided to recommend the use of Enhancement, a parameter for the spatial frequency processing, only at a level less than 2 for the CXDI system.

**Table 1 Appropriate imaging parameters for gray-scale and spatial frequency processing recommended by the CR Taskforce in 2001 and the FPD DR Taskforce in 2007**

| | **CR-TF Recommendation** | **DR-TF Recommendation** |
|---|---|---|
| **Gray- scale (gradation) processing** | | |
| Lung field | 1.6 - 2.0 | 1.6 - 2.0 |
| Mediastinum, heart | 0.15 - 0.25 | not defined |
| **Spatial frequency processing**<br>High frequency (> 0.2 cycle/mm)<br>Low frequency (0 cycle/mm) | 1.0 - 1.2 | OFF* |

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**Note: CR-TF** is the **CR Taskforce**, while **DR-TF** is the **FPD DR Taskforce**. ***Spatial frequency processing** was recommended to be basically OFF for the any FPD, except CXDI (Canon, Inc.). The range recommended by the CR Taskforce is equivalent to Enhancement 0-4 for CXDI as in the Vender's recommendation in Table 3. The FPD DR Taskforce accepted the Enhancement 0 and 1 for CXDI after the group review (See **Table 3**).

**Table 2 Corresponding parameters of image processing: CR and CXDI**

| | **CR - Fuji** | **CR - Konica** | **CR - Kodak** | **DR Canon（CXDI）** |
|---|---|---|---|---|
| **Gray-scale Processing** | GA | G value | Contrast Factor | Contrast |
| | GC | | Upper Contrast | |
| | | | Lower Contrast | |
| | GS | Lung density | Density Shift | Brightness |
| | | | Shoulder Shift | |
| | | | Toe Shift | |
| | GT | LUT | | Curve shape |
| **Spatial frequency processing** | RN | Mask size | Matrix size | Frequency |
| | RE | Emphasized degree | High Density Boost | Enhancement |
| | | | Low Density Boost | |

**Note:** The parameters for the multi-frequency processing are not included in this table.

**Table 3 Appropriate imaging parameter for legal medical judgment of pneumoconiosis for CXDI (Canon, Inc., Tokyo)**

| | Vender's Recommendation | DR-TF Recommendation |
|---|---|---|
| Contrast | 14 - 17 | 14 - 17 |
| Brightness | 17 - 20 | 17 - 20 |
| Curve shape | Chest | Chest |
| Frequency | 7 | 7 |
| Enhancement | 0 - 4 | 0 - 1 |

**Note:** See also the Note for **Table 1.**

## II. Comparison of judgment of the grade of pneumoconiosis between film-screen system and Canon FPD DR system in the same patient

Using the parameters recommended by the FPD DR Taskforce, we have performed reading trials by the same five physicians who participated in the previous parameter study. In this study, we aimed to assess the consistency of classifications of profusion for hard copy radiographs from FPD DR compared to FS.

### Methods

The FPD DR Taskforce compared the hard copy of the FPD DR against the film-screen radiograph of the same patient and chose FPD DR processing parameters that appeared to produce an image most similar to the FS radiograph. We have identified 35 cases with a pair of hard copy FPD DR and FS radiographs from the Occupational Safety and Health Compensation Hospitals (Rosai Hospitals) and other academic groups with an interest in the pneumoconioses (Fukui University Hospital and NHO-Kinki Chuo Chest Medical Center). Five readers who serve as the regional or central Pneumoconiosis Examination Physicians independently classified these 35 pairs of FPD DR hard copy and FS radiographs, applying a 4 point profusion scale (0, 1, 2, and 3) according to the Japan Classification, which is almost parallel to the ILO/ICRP.

Crude agreement and Cohen's κ statistics were used to assess the consistency

between the classification results within the reader (intra-reader agreement), or between the readers (inter-reader agreement). Altman's criteria for the κ statistics interpretation was used to decide the agreement: poor <0.2, fair 0.21-0.40, moderate 0.41-0.60, good 0.61-0.80, and very good >0.81 (7).

**Results**

The median reading results of five readers' trial on the 35 pairs of the FPD DR hard copy and the FS radiograph were summarized in **Table 4** and **5**. Accumulation of 5 readers' individual reading results of 35 pairs showed crude agreement of 78.9% (138/175 readings) as well as 15.4% (27/175) DR's over-reading and 5.7% (10/175) DR's under-reading compared to FS radiograph (**Table 4**). Crude agreement between median profusion of FPD DR and FS radiograph as shown in **Table 5** was 82.86% and its κ statistics was 0.74 (Std. Error 0.1078). The intra-reader agreement was good (κ = 0.6975; range: 0.4909-0.7886). The inter-reader agreement was also good as the average κ value between FS radiograph and FPD DR was 0.6072 and 0.6968, respectively. From the results of this study, the capability of FPD DR in judging the profusion category of pneumoconiosis is similar to FS chest radiography.

**Table 4 Comparison of the profusion between FS and FPD DR chest radiography in 175 accumulated cases (5 readers, 35 patients)**

| FS – DR | Number of cases | FS>DR (Difference of the Profusion) | FS<DR (Difference of the Profusion) | FS=DR (Difference of the Profusion) |
|---|---|---|---|---|
| 0 - 0 | 45 | | | 45 |
| 0 - 1 | 11 | | 11 | |
| 1 - 0 | 3 | 3 | | |
| 1 - 1 | 63 | | | 63 |
| 1 – 2 | 8 | | 8 | |
| 2 – 1 | 3 | 3 | | |
| 2 – 2 | 22 | | | 22 |
| 2 – 3 | 8 | | 8 | |
| 3 – 2 | 4 | 4 | | |
| 3 – 3 | 8 | | | 8 |
| **Total (%)** | **175 (100)** | **10 (5.7)** | **27 (15.4)** | **138 (78.9)** |

**Table 5 Summary of the median profusion of five readers: FS vs DR**

| FS | 0 | 1 | 2 DR | 3 | Total |
|---|---|---|---|---|---|
| **0** | 9 | 3 | 0 | 0 | **12** |
| **1** | 0 | 14 | 1 | 0 | **15** |
| **2** | 0 | 0 | 4 | 1 | **5** |
| **3** | 0 | 0 | 1 | 2 | **3** |
| **Total** | **9** | **17** | **6** | **3** | **35** |

### III. Evaluation of appropriate FPD DR parameters in other FPD DR systems

The taskforce is aware that FPD DR systems produced by Philips, Siemens, GE, Toshiba, Hitachi, and Shimazu are available in Japan. Each of these venders was asked to submit a few typical pneumoconiosis cases for the evaluation by the FPD DR Taskforce. Various sets of parameter modifications were assessed by the same manner described above for the CXDI. After the evaluation in section **II**, the taskforce concluded that spatial frequency processing should be off for pneumoconioses screening radiographs. The multi-frequency processing that enable differential processing at the areas with high and low frequencies was also not allowed for the judgment of presence of pneumoconiotic opacities. The FPD DR Taskforce's recommendation was revised and is shown in the right in **Table 1**. Also the gray-scale processing of the mediastinum was omitted, in

contrast to the previous CR recommendations.

**Table 6 Applicable imaging parameters for each vender to match the recommendation by the FPD DR Taskforce for MHWL-J in 2007**

| | | |
|---|---|---|
| Canon | E<br>D<br>Brightness<br>Contrast | * or 1<br>*****<br>17 – 20<br>14 – 17 |
| Philips | Density (D)<br>Gamma (G)<br>NC (N)<br>DCE | 15 – 17<br>10 – 45<br>00 – 03<br>0.0 |
| Siemens | SF<br>H<br>LUT<br>W<br>C | 0/***<br>0/***<br>8<br>2300 – 3300<br>1900 – 2300 |
| GE | Contrast (C)<br>Brightness (B)<br>Edge (E) | 119 – 130<br>152 – 157<br>1 |
| Toshiba | WL<br>WW<br>G<br>E<br>D<br>I | 1800 – 2400<br>1200 – 2800<br>7<br>0<br>0<br>0 |
| Hitachi | Filter<br>Mask Size<br>DRC<br>Gamma (γ)<br>WL<br>WW | 0 – 3<br>5<br>0<br>3<br>2100<br>3850 |
| Shimazu | W<br>L<br>E | 11500 – 12500<br>6000 – 6500<br>0 |

Note *, *****, *** are off.

As stated in the note of the table, the taskforce reviewed CXDI hardcopies and accepted the use of Enhancement, a parameter for the spatial frequency processing, up to 1, while the CR Taskforce recommendation was equivalent to the CXDI's Enhancement up to 4, as shown in the vender's recommendation in **Table 3**. For the other FPD DR venders, the taskforce only reviewed hardcopies produced with Spatial Frequency Processing OFF, and the images were considered acceptable. The sharpness of the opacity edges may to a great extent be affected by Enhancement, but other factors like the distance between the subject and the film-screen or the flat-panel detector may also affect the sharpness of the images.

In order to perform a group review, the taskforce requested the venders to submit hardcopies produced according to the recommendation shown in **Table 1**. **Table 6** summarizes the parameter set for the each vender which is compatible with the FPD DR Taskforce's recommendation for the processing of FPD DR. The contrast, the density, and the edge enhancement seem to be comparable parameters for the majority of the venders, although there is no detailed explanation. Some of the venders include window width and level, while the others do not.

**Discussion**

For most physicians who use images from CR or FPD DR systems in clinical practice, there is little importance attached to ensuring strict comparability to FS radiographs, and the present study may have little impact on their practice. The laser-printed hard copies or digital images viewed on medical display monitors are produced routinely according to pre-selected processing parameters recommended by the system vender or by the hospital's chief radiologist; image processing is a 'black box' to most physicians. Because of limited storage media, PACS often only retain the processed and compressed **For Presentation** data needed for displaying the images. After compression, any pre-storage modified parameters for the gray scale processing and the spatial frequency processing cannot be restored. It is not the window level or width of the stored image but the pre-storage parameter settings that are critical to the visualization of the appropriate image.

Therefore, the images stored on PACS are usually different from the raw **For Processing** data and modification based upon the original image data may not be possible. DICOM Part 14 is the latest standard adopted to ensure compatibility of the image data for medical display monitors or medical laser printers. The DICOM Part 14 provides a standardized format for gray scale display, and requires P-values, *i.e.* the pixel value after

all DICOM defined gray scale transformations have been applied (8). Such a standardized format for gray scale will be a minimum requirement for future data collections for pneumoconiosis applications. Certain DICOM formatted CR images cannot be properly visualized on high-resolution medical monitors, due to the inability to apply DICOM Part 14. For research purposes, image data should be obtained as raw, modifiable, **For Processing** data, and stored uncompressed or using lossless compression. Such data formats may not be available without the venders' assistance. It may not be practical at this time to require that all CR or FPD DR data be stored as raw **For Processing** data, but it is essential to demand that all the digital radiograph data be stored using P-values as defined in DICOM Part 14.

DICOM Part 14 guarantees the standardization of gray scale, but it does not guarantee the standardization of other parameters such as spatial frequency processing, multi-frequency processing, and dynamic range control. The multi-frequency processing enables differential processing in areas with higher and lower frequencies. The dynamic range control is a pre-storage processing that permits viewing detail behind the heart and diaphragm shadows, while retaining the gray-scale and detail of the lung fields; it may be useful for other clinical purposes but is not permitted for the legal medical judgment of pneumoconiosis in Japan. These parameters were designed for better visualization of FPD DR images, and may enable demonstration of certain pathologic lesions more clearly, but standardization of those parameters has not been achieved yet.

Film-based hard copies of FPD DR were evaluated concerning the appropriate image processing parameters and the consistency of pneumoconiosis classification results, in comparison to conventional FS radiographs. When the recommended parameters were applied, hard copies of FPD DR were judged similar to FS in brightness and gray-scale contrast. The authors have recently reported a similar study, which included comparisons with both FPD DR and CR, using 10 definite, 10 borderline and 10 negative

cases, with HRCT as the ‘gold standard’ (9). After technical optimization, the FPD DR images were very similar to the FS radiographs, while the CR hard copies were not as similar, when compared to the FPD DR, however, that study did not detect a difference among the three modalities’ area under the curve (AUC) of the ROC analyses, when the HRCT-validated FS radiograph reading results were considered as the gold standard.

The present study, performed by the DR Taskforce, used the previous recommendations of the CR Taskforce for MHWL-J as a starting point. The new FPD DR Taskforce recommendations are more rigorous than the earlier one, in not allowing the use of the spatial frequency processing for FDP DR. This new report may urge reconsideration of the previous CR Taskforce recommendation in this regard.

**Conclusion**

The MHWL-J FPD DR Taskforce has concluded that the FPD DR chest radiography, with appropriate settings as presented in this article, can be used in the legal management of patients with pneumoconiosis. Accordingly, in Japan FPD DR was officially approved for the purpose of pneumoconiosis judgments in December 2007. The pre-storage parameters, both gray scale processing and spatial frequency processing, as well as the post-storage parameters like window level and width, are important in determining the image output. Those influences on the display of a chest image are universal when viewing either hard copy or soft copy images. DICOM Part 14 should be included as the required grayscale format. Evaluation of soft copy images on a CRT or LCD monitor was not included in the scope of the evaluation performed by the MHWL-J FPD DR Taskforce. Implementation of the use of digital soft copy images for pneumoconiosis judgments will entail a rigorous evaluation of monitor specifications, maintenance, and calibration, as well as data storage, data compression, and pre-storage data processing.

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