Asbestos-Related Pleural Abnormalities Detected by Chest X-Ray: Fair Agreement with Detection by Computed Tomography

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Abstract: Asbestos-Related Pleural Abnormalities Detected by Chest X-Ray: Fair Agreement with Detection by Computed Tomography: Narufumi Suganuma, et al. Department of Environmental Health, Fukui Medical University School of Medicine, Fukui

The International Labour Office (ILO) 1980 International Classification of Radiograph for Pneumoconioses (ILO 1980) is used widely round the world for the evaluation of dust-exposed workers, whereas computed tomography (CT) has been introduced for more accurate diagnosis of pneumoconioses. This study is aimed to assess whether the chest X-ray can detect pleural abnormalities as accurately as CT in patients with asbestos-related lung diseases in the early stages. Eighty subjects with positive finding in 10 cm × 10 cm CXR were selected from 1178 ex-workers with asbestos exposure for the study. They underwent CXR and CT to be assessed by two ILO 1980 experts for CXR and a chest physician and a radiologist for CT films according to ILO 1980 and the CT criteria, respectively, which we developed. The CT and CXR readings were obtained independently. Scores of the extent of pleural abnormalities agreed on by two readers were compared in CT and CXR. Sensitivity and specificity of CXR for detecting pleural abnormalities by CT result as a gold standard were also calculated. Among the 80 subjects, there were 66 patients (83%) who had pleural abnormalities detected by CXR. Of these 66 persons, CT confirmed 61 subjects to have pleural plaque. The reading results of CXR and CT showed fair agreement with Cohen’s weighted kappa of 0.53. Sensitivity and specificity of CXR and CT were 0.94 and 0.73, respectively. Fair agreement was seen between CXR and CT in detecting pleural plaque in terms of extent in dust-exposed workers. Such a standardised system as ILO 1980, CXR is still useful for the screening for pleural abnormalities in dust-exposed individuals. (J Occup Health 2001; 43: 365–370)

Key words: Asbestos-related pleural thickening, chest X-ray, computed tomography, measurement system, ILO 1980

The International Labour Office (ILO) developed the International Classification of Radiograph for Pneumoconioses (ILO 1980) for the purpose of coding anterio-posterior chest X-ray in a reproducible manner, which has been used round the world for epidemiologic research, surveillance, and medical checks of dust-exposed workers. This widespread use of ILO 1980 has enabled physicians to classify radiographic manifestations in workers at risk of pneumoconioses in a semi-quantitative way, which resulted in making workers realise pulmonary involvement at an early stage and to take preventive measures. Since most of the severe cases of advanced pneumoconioses with impaired lung function are detected easily with a chest X-ray, how to detect early cases of pneumoconioses became a matter of question. Among pneumoconioses, asbestos-related respiratory diseases are of major burden even in developed countries because of malignant complication of the diseases. The number of cases of malignant mesothelioma is shown to correlate well with amount of asbestos consumption. Being one of the biggest consumers of asbestos, although most of them are chrysotiles, Japan will confront an epidemic of asbestos-related malignancy in the near future.

The Pneumoconiosis law of Japan requires employers with dusty workplaces to make employees to have a
medical check periodically by CXR, not by CT. These radiographs are assessed and classified according to the Japanese classification\(^3\), which is a modification of ILO 1980. When the dust is asbestos, another law also requires the worker to be screened by CXR for lung cancer and malignant mesothelioma.

Not all workers with possible dust exposure, however, are covered by the pneumoconioses screening system in Japan. In the workplace that we are following up which used to have low dose asbestos exposure, a few, not all, units of workers were screened by the usual CXR for asbestos-related respiratory diseases. Even in such workplace, 10 cm × 10 cm CXR, which is used in Japan as an inexpensive substitute for the usual CXR, is performed for all workers in order to rule out pulmonary tuberculosis. This technique was introduced to screen all persons susceptible to pulmonary tuberculosis when the disease was a national threat in 1940’s. The technique is still popular and used in the workplace for legitimate annual medical checks of employees.

Concerning Computed tomography, it was Kreeel who first introduced the apparatus for the assessment of pleural thickening in asbestos exposed individuals\(^6\). Hosoda \textit{et al.} also reported the superiority of CT to the usual chest X-ray (CXR) in detecting pleural abnormalities\(^1\). By dividing lungs into many slices, CT made it easy to understand condensed information on lung diseases projected on a two-dimensional plain radiograph.

Some developed countries have recently started to see whether CT or HRCT can be employed as a screening test for a dust-exposed population. In Germany they have tested about 600 dust-exposed persons by CT/HRCT and classified the result according to German Classification developed by Hering \textit{et al.}\(^6\)–\(^8\). Finnish researchers have also developed a similar classification, which specially deals with asbestos-related lung diseases, and have screened over 600 persons with asbestos exposure\(^9\)–\(^10\). A French group, too, have introduced HRCT for the screening of the dust-exposed\(^11\)–\(^12\).

In Japan, 66.5\% (6,310/9,490) of public and private hospitals with more than 20 beds had CT scanners in 1996\(^13\), which is exceptionally high compared to the situation even in other developed countries. Evidently CT apparatus is not available at every clinic where dust-exposed workers are examined and followed up.

Although spatial resolution is lower than CT, both radiation and cost of CXR are much lower than those of CT. To make the most of the accurate resolution of normal and pathological pulmonary architecture and to reduce the radiation exposure, CT should be used as a supportive procedure for conventional screening with CXR.

Assessment of conventional screening by CXR is, therefore, needed to see whether its reading is acceptable or not compared to CT. By knowing its weakness, it will be possible, with the utilisation of advanced technology, to improve sensitivity and specificity of this inexpensive screening test.

This study is aimed to compare these two diagnostic measures of CXR and CT, in detecting pleural thickening in patients with asbestos-related lung diseases in the early stages. In order to compare CXR and CT, we have developed criteria for CT to measure pleural abnormalities to take into account the three-dimensional extent of the lesion.

**Subjects and Methods**

**Subjects**

Eighty-two ex-workers with positive findings of pleural changes in 10 cm × 10 cm chest X-rays through 1983 to 1991 were selected as subjects for the present study, but one subject with multiple tumour lesions on CXR and another whose CXR film was unavailable were excluded from the subjects. They were among 1178 ex-workers in a factory that dealt with the repair of steam locomotives and were among the cohort followed up at Sapporo Railway Hospital\(^14\). An average age of the 80 subjects was 57.8 yr with a standard deviation of 9.1 yr. Years of exposure to asbestos were available for 22 subjects among them, and showed an average and standard deviation of 18.9 yr and 11.9 yr, respectively. Although the smoking history of thesubjects was not available, more than two thirds of the factory worker had been reported to be smokers.

**CXR and CT**

Chest X-ray and CT scan were performed in selected subjects to be reviewed by experienced chest physicians and radiologists. A high voltage posterior-anterior radiograph of the chest (CXR) was taken of each of the subjects. The scanners used for CT were GE8800 or GE9800 quick (General Electrics). The kilovolt peak, miliamperes and the scan time during the CT scanning were 120 kVp, 170 to 200 mA, and 2 to 8 sec, respectively. The slices were obtained from the apex to the base of lungs by 5 to 10 mm collimation with a 10 mm interval. The obtained images were visualised with a window width/level for the parenchyma of 1200 to 1500/700 to 600, and those for the mediastinum of 300 to 400/30. The pleural abnormalities detected by the chest X-ray were described according to the ILO 1980 classification and by CT according to the criteria explained bellow.

**Description Methods**

We have developed criteria for the extent of pleural thickening by CT to give a semi-quantitative description of the findings. As shown in Table 1 and Fig. 1, not only the horizontal extent but also the vertical extent of pleural abnormalities was taken into consideration: for each case, apexes, upper chest walls, middle chest walls, lower chest
walls, diaphragm, para-pericardia, para-vertebra and the costophrenic angle. The major diameter of each pleural thickening was determined by choosing which of the following is longer, the horizontal length on the CT slices or the vertical length that is calculated by multiplying the interval between slices by the number of slices involved in the lesion. We summed up the major diameters of all the pleural abnormalities found in each area described above and decided the class of the extent of pleural thickening in the area. A length less than 5 cm was considered to be Class 1, 5 cm to 10 cm as Class 2, and more than 10 cm as Class 3. The class of severest extent among those, which were decided for overall area on the reading sheet, was reported as the representative class of the extent in each case.

A chest physician and a radiologist reviewed the CT films to describe pleural abnormalities according to the developed criteria. The class of extent was decided by agreement of the two readers. Independently to the CT reading, two physicians who were experts on the ILO classifications read the CXR films and described the extent of pleural abnormalities according to ILO 1980. One of the CXR readers was a B-reader qualified by National Institute of Occupational Safety and Health (NIOSH) of U.S.A. The scores of the extent of pleural abnormalities on CT and CXR agreed on by two readers were compared.

Statistical Evaluation

The main analysis to assess agreement on the extent of pleural thickening in CXR and CT was done with Cohen’s weighted kappa coefficient. Interpretation of kappa value was done according to the criteria described by Fleiss[15]. A kappa value less than 0.40 was interpreted as poor agreement, between 0.40 and 0.70 as fair to good agreement, and 0.70 and more as excellent agreement. The sensitivity and specificity of CXR for detecting pleural thickening were also calculated with the CT result as the gold standard.

Results

The classes of pleural thickening detected by CXR and CT were shown in Table 2. Among the 80 subjects, 65 patients (83%) had pleural thickening detected by CXR. Of the 65 persons, CT confirmed 61 subjects to have pleural thickening. The reading results of CXR and CT showed fair agreement with Cohen’s weighted kappa of 0.53. The sensitivity and specificity of CXR compared to CT were 0.94 and 0.73, respectively. In one patient (2.5%) pleural thickening was detectable only with CT, and four patients without thickening by CT were falsely described as positive on chest X-ray. One of the four false positive cases had irregular opacities both on CXR and CT.

Discussion

Fair consistency of CXR and CT

The fair agreement was shown between CXR and CT in detecting pleural thickening in terms of extent in dust-exposed workers. It can be considered that CT is the gold standard because of its high resolution in 3 dimensions and its good correlation with pathology. With such a standardised system as ILO 1980, CXR is still useful with high sensitivity and specificity for the screening for pleural thickening.

This could be a good reason to back up the screening of dust-exposed workers and ex-workers by radiographs, which can be done at lower cost. Technological innovation has brought accurate diagnosis of dust-related pulmonary diseases, but not all dust-exposed workers are able to have the benefit of new modalities like HRCT. In that sense, simple and inexpensive diagnostic tests such as CXR should continue to be assessed to maximise their sensitivity and specificity. Computed radiographs and digital radiograph could be used to enhance the diagnostic capacity of plain CXR.

Some may argue that if CT were used for screening all subjects in a cohort instead of 10 cm x 10 cm radiographs,
false negative cases detected by CXR would be much larger in number. Another reason why we obtained good sensitivity with CXR is that in our cases there were few parenchymal lesions that perplex readers in assessment of pleura on CXR. Our main research question, however, was to compare two modalities in the detection of pleural abnormalities, not to describe the sensitivity and specificity of chest X rays. Sample selection criteria in this study are, thus, acceptable to assess the comparability of CXR and CT.

In describing parenchymal manifestations, the sensitivity of CXR differs among some modifications of
Table 2. Extent of pleural abnormalities described by CT and CXR

<table>
<thead>
<tr>
<th>Extent by CT</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent by CXR</td>
<td>15</td>
<td>28</td>
<td>11</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

See Table 1 for definition of extent 1, 2, 3 of pleural abnormalities in ILO 1980 and CT classifications.

ILO 1980. Kusaka et al. reported that the Japanese Classification of Radiographs of Pneumoconioses (JC), which includes O/1 and I/0 standard films, gave higher profusion than the ILO 1980 in describing boundary pneumoconiotic cases. Harkin et al. showed that taking lung function as the gold standard radiograph with profusion of 0/1 according to ILO 1980 was more sensitive than HRCT. These two reports suggested that CXR with a lower cut off point could continue to be used as a sensitive and inexpensive screening test.

CT classification as the gold standard for CXR

Authors have already developed the Japanese Classification of CT for Pneumoconioses, with the support of the Japan Industrial Safety and Health Association (JISHA). This classification will enable researchers to compare readings by CT with those by CXR easily in a semi-quantitative way. Also the International Classification of HRCT for Pneumoconioses, for which we are collaborating with experts from 6 nations, namely, Germany, Finland, U.S.A., France, Belgium and U.K., will provide us with detailed information on very early manifestation of pneumoconioses, or of even pneumoconioses-to-be. Feedback from such studies will help to show a semi-quantitative correlation between plain chest radiograph either in analogue (conventional CXR) or digital (CR or DR) and CT.

Controversy on significance of pleural thickening

The significance of measuring the extent of pleural abnormalities in asbestos-exposed individuals has been controversial. It is considered to have little correlation to the severity of the diseases but to be associated with past exposure period of the individual. Kishimoto et al. showed number of asbestos fibres in autopsied lungs correlated closely with the severity of pleural thickening. Increased number of pleural thickening was reported to be a risk indicator of mesothelioma. Another report shows that a longer latency period after asbestos exposure makes the risk of lung cancer greater even without radiographic asbestosis. Therefore, reliable quantitative classification of pleural abnormalities is needed to end the controversy.

Screening for malignancy and benign lung diseases

Under the legal system on occupational safety and health in Japan, there are basically two radiological screenings performed for dust-exposed persons. As some of the dusts occupationally encountered are carcinogenic, radiological screening for the dust-exposed individuals is aimed at the early detection of malignant complications associated with dust-exposure, that is, lung cancer and malignant mesothelioma, which are the severest biological effect caused by exposure to carcinogenic dust such as asbestos. CXR is also used as a source of surveillance data to monitor the prevalence of benign lung or extra-lung diseases caused by dust-exposure. Even if the extent of pleural thickening is proved not to suggest increased risk of lung cancer and malignant mesothelioma, the lowest effects of asbestos should continue to be monitored to prevent new cases of asbestos-induced malignancy.

In conclusion, showing fair consistency with CT readings in detecting pleural thickening, chest radiograph is still inevitable as the screening method for pleural thickening in terms of accessibility, low cost and less radiation exposure than with the CT scan.

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